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UNDESCRIBED PLANTS FROM GUATEMALA AND OTHER CENTRAL AMERICAN REPUBLICS. XXXI[1]

JOHN DONNELL SMITH

(WITH ONE FIGURE)

Magnolia guatemalensis Donn. Sm.—Glabra. Folia breviter petiolata elliptica apice acuta basi obtusiuscula concoloria subtus glabrescentia crebre penninervia. Sepala oblonga tenuiter coriacea 5-nervia. Petala spatulato-obovata coriacea. Stamina numerosissima. Gynophorum fusiforme.

Arbor 6–8-metralis. Folia supra cum ramulis petiolis pedunculo glabra subtus pilis sparsis castaneis aspersa vel denique glabra 12–16^{cm} longa 5.5–8.5^{cm} lata plerumque abrupte breviterque cuspidata, costa subtus tuberculato-rugosa, nervis lateralibus utrinque 13–16, interjectis minoribus vix ullis, petiolis 1.5–2^{cm} longis apice canaliculatis ceterum teretibus. Pedunculus 3^{cm} longus, stipulis foliorum nascentium 8–15^{mm} longis passim castaneo-pubescentibus. Sepala 58–60^{mm} longa 21–22^{mm} lata ima basi 6–8^{mm} lata humectate pellucido-punctulata. Petala 65–70^{mm} longa 29^{mm} lata ima basi 2–3^{mm} lata opaca cum sepalis obtusa glabra nivea. Receptaculum staminale 6^{mm} longum 4^{mm}-diametrale, staminibus circiter 95. Gynophorum 25^{mm} longum medio 9^{mm}-diametrale, carpellis circiter 22–24 dorso sulcatis in stigma 4^{mm} longum recurvatum attenuatis. Fructus desideratur.—*M. portoricensi* Bello proxima differt praesertim glabritate.

In palude profunda prope Tactic, Depart. Alta Verapaz, Guatemala, alt. 1550^{m}, Mart. 1908, *H. von Tuerckheim* (n. II. 2165).

Marila verapazensis Donn. Sm.—Folia supra glabra subtus nervis puberula et diaphano-punctulata ceterum opaca oblonga acute curvilineo-cuspidata basi acutiuscula. Racemi folia subaequantes puberuli. Sepala ovata vel ovalia pedicellum aequantia petalis obovato-oblongis paulo breviora. Antherae in appendicem linearem productae. Stylus ovario vix brevior, stigmate minimo.

[1] Continued from BOT. GAZETTE **46**:117. 1908.

Ramuli glabri. Folia coriacea 18–20^{cm} longa medio 6–6.5^{cm} lata, nervis subtus elevatis et pallidis, lateralibus parallelis utrinque 13–15 sub ipso margine arcuatis, venis transversis undulatis, venulis minute reticulatis, petiolis 12–15^{mm} longis. Racemi fere a basi floriferi prope basin ramum nonnunquam emittentes, pedicellis inordinatim dissitis puberulis, floribus pentameris. Sepala in alabastro puberula post anthesin deflexa 7–8^{mm} longa, 3 exteriora late obtuseque ovata interioribus suborbicularibus paulo angustiora. Petala 9^{mm} longa apice 3–4^{mm} basi 1^{mm} lata. Stamina 4–5^{mm} longa, antheris appendice eis paulo breviore computata 2^{mm} longis. Ovarium glabrum elongato-oblongum, stylo 5^{mm} longo, stigmate pyramidato 1^{mm} longo. Capsula ignota.—*M. macrophyllae* Benth. proxima.

In silvis montanis ad praedium *Cubilquitz* dictum, Depart. Alta Verapaz, Guatemala, alt. 350^{m}, Oct. 1904, *H. von Tuerckheim*, n. 8660 ex Pl. Guat. etc. quas ed. Donn. Sm.

Leandra (§CARASSANAE Cogn.) **Tuerckheimii** Donn. Sm.—Ramuli teretes uti petioli paniculae calyces strigillosi. Folia ovato-oblonga vel -lanceolata incurvo-acuminata basi acuta septuplinervia discoloria supra tuberculato-setosa subtus foveolata pubescentia. Flores ebracteolati. Calycis lobi interiores brevissimi, segmenta exteriora filiformia tubum aequantia.

Ramuli dichotomi. Strigillae densae arcte appressae purpurascentes. Folia leviter disparia rigida inter bullas diaphana supra intense viridia setis crassis curvatis armata subtus pallida nervis strigillosa venis pubescentia 7–11^{cm} longa infra medium 3–4.5^{cm} lata basi inaequalia, petiolis in eodem jugo inaequalibus 1.5–3^{cm} longis. Paniculae terminales singulae vel 2–3-nae trichotomae 6–7.5^{cm} longae, bracteolis lineari-lanceolatis 1.5–2^{mm} longis, pedicellis 1.5–2^{mm} longis, floribus 5-meris. Calyx longe strigillosus, tubo campanulato 3–4^{mm} longo infra limbum non constricto, lobis interioribus vix 0.5^{mm} longis semiorbicularibus. Petala oblongo-ovata 4–5^{mm} longa. Stamina 10, antheris 1.5^{mm} longis filamenta compressa aequantibus, connectivo infra loculos haud producto. Ovarium vertice convexo glabrum 5-loculare, stylo 4–5^{mm} longo. Bacca non adest.—Secundum methodum clari *Cogniaux* juxta *L. strigilliflora*m Cogn. locanda.

In summo monte silvestri prope Cobán, Depart. Alta Verapaz, Guatemala, alt. 1600^{m}, Jun. 1908, *H. von Tuerckheim* (n. II. 2369).

Hoffmannia Tuerckheimii Donn. Sm.—Pubes undique paleae- et monili-formis. Folia inter minora longiuscule petiolata ovata vel ovalia contracto-acuminata basi acuta vel rotundata supra nitida subtus prasertim ad nervis pubescentia. Flores fasciculati subsessiles pubescentes. Calycis tubus obovatus lobis subulatis bis

longior corolla partita 6-plo superatus. Filamenta antheris triente breviora.

Ramuli dichotomi teretes lenticellati fusco-pubescentes, stipulis triangularibus. Folia coriacea 5–6.5^{cm} longa 2.5–4^{cm} lata subtus pallida et inter nervos subtilius pubescentia, nervis lateralibus utrinque 5–7, petiolis 15–22^{mm} longis. Pedunculus vix ullus nodiformis glandulosus, pedicellis 3–10-nis 1^{mm} longis, floribus tetrameris 14^{mm} longis. Calyx tetragonus 3^{mm} longus sinubus glandulosus. Corolla sparsius pubescens 12^{mm} longa, segmentis linearibus tubo 5-plo longioribus. Stamina fauci inserta 5^{mm} longa, antheris lineari-oblongis. Stylus corolla paulo brevior, stigmatibus 2 linearibus 2^{mm} longis. Bacca deest.

In silvis supremis montis prope Cobán, Depart. Alta Verapaz, Guatemala, alt. 1600^{m}, Mart. 1908, *H. von Tuerckheim* (n. II. 2160).

Guettarda (§ULOLOBUS DC.) **cobanensis** Donn. Sm.—Folia ternatim verticillata longe petiolata oblongo-elliptica sursum subsensim deorsum contractius acuminata glabrescentia. Stipulae internodiis superioribus breviores. Flores 4–5-meri. Corolla inter longiores, tubo calycem 7-plo lobos proprios 3-plo stylum dimidio superante. Drupa glabra, putamine 3–4-loculari atque -quetro, lobis intermediis saepius adjectis.

Ramuli obtuse trigoni pubescentes, internodiis inferioribus 1^{cm} superioribus 2^{cm} longis, stipulis ovatis 5^{mm} longis extus medio intus undique cano-sericeis. Folia juniora supra fere glabra subtus nervis venisque appresse sericeis argentea, provectiora utrinque nitida 15–20^{cm} longa medio 7.5–9^{cm} lata, nervis lateralibus utrinque 12–13, venis transversis creberrimis pellucidis, petiolis pubescentibus 2–7^{cm} longis et foliis in eodem verticillo inaequalibus. Cymae pubescentes furcatae, pedunculo 1.5–2^{cm} longo, bracteis lanceolatis 1^{mm} longis, floribus sericeis. Calycis 3^{mm} longi limbus brevis dentatus persistens. Corollae tubus cylindricus 22^{mm} longus, lobi lacerato-crispati. Antherae 4^{mm} longae. Ovarium tetragonum, stylo 14^{mm} longo cano-pubescente, stigmate capitato. Drupa ovoidea 10^{mm} longa 7^{mm} lata calycis limbo coronata, putamine osseo profunde acuteque 3–7-lobato, loculis rectis.—*G. crispiflorae* Vahl proxima.

In silvis montanis prope oppidum Cobán, Depart. Alta Verapaz, Guatemala, alt. 1500^{m}, Jan. 1908, *H. von Tuerckheim* (n. II. 2096).

Chomelia brachypoda Donn. Sm.—Inermis. Folia glabrescentia oblongo-lanceolata utrinque acuminata paucinervia transversim venulosa. Pedunculi petiolis parum longiores, cymis laxe paucifloris et floribus paene glabris. Calyx subsessilis oblongus minute denticulatus. Corollae tubus anguste cylindricus calyce 4-plo lobis propriis 5–6-plo longior.

Ramuli petioli stipulae pedunculi appresse pilosi, cymis calycibus corollae lobis sparsim pilosiusculis. Folia 7–10^{cm} longa medio 2.5–3^{cm} lata sursum tenuiter acuteque incurvo-angustata deorsum subsensim acuminata chartacea in sicco viridia supra glabra subtus pilis raris aspersa et axillis barbata, nervis lateralibus utrinsecus 4–5, venulis erga lucem inspectis manifestis creberrimis undulatis, petiolis 5–6^{mm} longis, stipulis filiforme linearibus 6–8^{mm} longis. Pedunculi 5–8^{mm} longi medio bibracteolati, cymis 4–8-floris, pedicellis brevissimis crassis. Calyx 2.5–3^{mm} longus, denticulis triangularibus vix 0.5^{mm} longis. Corollae tubus glaberrimus 11–12^{mm} longus, lobis ellipticis 2^{mm} longis. Antherae inclusae vix 2^{mm} longae. Ovarium calyce dimidio brevius, stylo ramis 2^{mm} longis computatis 7^{mm} longo, ovulis linearibus. Drupa desideratur.—Ob folia *C. filipedi* Benth. valde affinis differt praesertim pedunculis perbrevibus.

Ad ripas fluminis Ogewaj prope Sasís, Depart. Alta Verapaz, Guatemala, alt. 900^{m}, Maj. 1908, *H. von Tuerckheim* (n. II. 2253).

Satyria meiantha Donn. Sm.—Folia juniora lanceolato-oblonga tenuiter acuminata basi acuta, provectiora ovalia bis longiora quam latiora utrinque subaequaliter angustata praetermisso utroque nervulo basali mox evanido triplinervia. Corymbi sessiles subsimplices, floribus minimis. Antherae tubo filamentorum paulo longiores apice acutae.

Frutex grandis congeneribus habitu similis. Folia in ramulis annotinis 13–17^{cm} longa 4.5–6^{cm} lata, in ligno vetere 18–19^{cm} longa 9^{cm} lata, nervis lateralibus utrinsecus 5–7, petiolis 1–1.5^{cm} longis. Corymbi ad nodos defoliatos 2.5–3^{cm} longi 8–14-flori, axibus confertis plerumque simplicibus 1^{cm} longis, bracteolis lanceolato-ovatis, basalibus 2^{mm} longis, medialibus 2 suboppositis 1^{mm} longis. Calycis tubus 1.5^{mm} longus 2^{mm}-diametralis basi intrusus, limbus dentatus 1^{mm} altus. Corolla 11–12^{mm} longa etiam in sicco laete rosea minutissime puberula, lobis ovatis apiculatis membrana connexis. Stamina 5.5–6^{mm} longa, filamentorum tubo 2.5–3^{mm} longo, antheris majoribus 3–3.5^{mm} longis, omnium tubis sursum dilatatis apice acuto discretis, poris oblongo-ellipticis. Stylus paulo exsertus. Baccae deficiunt.

In silva montana prope Cobán, Depart. Alta Verapaz, Guatemala, alt. 1600^{m}, Jan. 1908, *H. von Tuerckheim* (n. II. 2101).

Gonolobus (§MONOSTEMMA K. Schum.) **patalensis** Donn. Sm.—Folia oblongo-ovata acuminata leviter cordata sparsim minuteque strigillosa. Flores umbellatim cymosi. Corolla calyce 3-plo longior intus glabra colorato-reticulata lobis ovato-oblongis alte fissa. Corona cyathiformis gynostegium subincludens ab eo libera squamulis minutissimis bifidis 5-denticulata intus infra marginem squamula minuta cum marginalibus alternante instructa.

Suffrutex volubilis, ramis petiolis cymis calyce patenter pilosis. Folia 7–11^{cm} longa 3.5–6^{cm} lata, sinu aperto acuto, nervis lateralibus utrinque 5–6, petiolis 15–30^{mm} longis. Pedunculus 10–13^{mm} longus, pedicellis plerumque 5-nis 15–20^{mm} longis. Calycis partiti segmenta lineari-lanceolata 5^{mm} longa. Corolla 14^{mm} longa rotata extus pilis raris aspersa, lobis 10^{mm} longis obtusis. Corona 2^{mm} alta 3^{mm} lata. Pollinia pendula obovata. Folliculi ignoti.—Secundum conspectum a cl. *Schumann* ad coronam ordinatum gregi "Bb" ascribendus.

Patal, Depart. Baja Verapaz, Guatemala, alt. 1600^{m}, Jul. 1908, *H. von Tuerckheim* (n. II. 2371).

Gonolobus (§MONOSTEMMA K. Schum.) **araneosus** Donn. Sm.—Folia oblongo- vel lanceolato-ovata acuminata leviter cordata molliter pilosa. Cymae umbelliformes petiolum paulo superantes, floribus inter minimos. Corolla calyce dimidio longior colorato-reticulata usque ad medium lobata intus praeter lobos triangulari-ovatos glabros niveo-arachnoidea. Corona cyathiformis gynophorum aequans ab eo libera callis bipartitis 5-denticulata, squamula interna minuta cum callis alternante.

Suffrutex volubilis, ramis petiolis cymis calyce patenter pilosis. Folia juniora sericea lineari-lanceolata, provectiora 6–8^{cm} longa 2.5–3.5^{cm} lata, sinu aperto acuto, nervis lateralibus utrinque 4–5, petiolis 10–20^{mm} longis. Pedunculus 3–5^{mm} longus, pedicellis 4–5-nis 3–7^{mm} longis. Calycis partiti segmenta lineari-lanceolata 5^{mm} longa. Corolla 8^{mm} longa rotata, lobis 4–4.5^{mm} longis acutis extus parce pilosiusculis apice ciliatis. Corona 1^{mm} alta 2^{mm} lata. Pollinia pendula compresso-orbicularia. Folliculi desiderantur.—Ad speciem praecedentem foliis calyce corona arcte accedens inflorescentia atque corolla insigniter recedit.

In montibus inter Tactic et Cobán, Depart. Alta Verapaz, Guatemala, alt. 1650^{m}, Jul. 1908, *H. von Tuerckheim* (n. II. 2332).

Merinthopodium campanulatum Donn. Sm.—Pedicelli filiformes floribus permagnis paulo breviores. Corolla sepalis bis fere longior e fundo subcylindrico abrupte lateque dilatata, lobis elongato-triangularibus, sinubus acutis.

Epiphytale, foliis coriaceis ovalibus acutis (ex cl. repertore in literis). Pedicelli 6.5–8^{cm} longi. Sepala acutissima apiculata 5.1–5.3^{cm} longa basi 1.6–1.7^{cm} lata. Corollae virescentis in toto 10^{cm} longae pars tubiformis 2.6^{cm} longa, pars campaniformis 5.2^{cm} longa in sicco tam lata quam longa, lobi 2.2^{cm} longi, sinubus obsolete plicatis. Antherae 1.7^{cm} longae. Stylus 8^{cm} longus.

Quanquam folia non vidi, tamen ob flores ab eis *M. neuranthi* Donn. Sm. optime discrepantes plantam publici juris faciendam puto.

In silvis primaevis superioribus montis haud procul a Cobán, Depart. Alta Verapaz, alt. 1600^{m}, Mart. 1908, *H. von Tuerckheim* (II. 2391).

Neotuerckheimia Donn. Sm., nov. gen. BIGNONIACEARUM e tribu CRESCENTIEARUM.—Calyx coriaceus glaber primum clausus denique in lobos 2 ovales inaequaliter ruptus. Corolla infra medium tubuloso-campanulata medio antice ad plicam transversam deorsum flexam geniculata ventricosa, limbo obliquo vix lobato crispatim dentato. Stamina 4 didynima inclusa paulo supra basin corollae inserta, loculis oblongis pendulis. Discus pulvinatus. Ovarium conicum costis 8 angulatum perfecte uniloculare, placentis 2 parietalibus valde intrusis, ovulis pluriserialibus, stylo angulato, stigmate bilamoso.—Arbores glabrae. Folia singula vel 3-fasciculata oblanceolata subsessilia. Nodi floriferi laterales vel terminales bracteis numerosis obtecti, pedunculis 1–5-nis. Corollae tubus plurinervis, limbus colorato-reticulatus.

In honorem nominavi liberi baronis *H. von Tuerckheim* floram Guatemalensem ad cognoscendam viginti tres per annos collaboratoris amicissimi.

FIG. 1.—*Neotuerckheimia megalophylla; fructus.*

Neotuerckheimia megalophylla Donn. Sm.—Folia 3-fasciculata incurvo- et falcato-acuminata deorsum longissime attenuata. Pedunculi laterales squamis permultis cartilagineis circumdati solitarii vel bini. Corolla calyce dimidio longior, tubo angusto. Fructus ovoideus utrinque acuminatus octangularis.

Arbor 10-metralis cortice suberosa rimosa. Fasciculi foliorum juniorum oblanceolato-linearium 20–28^{cm} longorum ad apicem versus ramulorum arcte conferti. Folia provectiora usque ad 76^{cm} longa 11–13^{cm} lata chartacea diaphana,

nervis lateralibus fortioribus utrinque 28–36, petiolis 6–8^{mm} longis tumidis corticatis. Nodi in ligno vetere floriferi squamis (seu bracteis pedunculos olim fulcientibus) concavis lanceolatis acutis armati, pedunculis 2–4^{cm} longis. Calyx 18^{mm} longus. Corolla 28^{mm} longa, plica retroflexa. Stamina 14–16^{mm} longa, loculis 4^{mm} longis. Discus 2^{mm} altus 3^{mm} latus. Ovarium 4^{mm} longum, stylo 13^{mm} longo. Fructus (*fig. 1*) nondum satis maturus 11^{cm} longus 7^{cm}-diametralis septis contrarie leviter compressus pericarpio cartilagineo tenui. Semina desunt.

Cubilquitz, Depart. Alta Verapaz, Guatemala, alt. 350^{m}, Sept. 1904, *H. von Tuerckheim*, n. 8723 ex Pl. Guat. etc. quas ed. Donn. Sm. Sub *Crescentia* olim distributa.—Ad ripas rivuli Chiú prope Cobán, Depart. Alta Verapaz, Guatemala, alt. 1350^{m}, Maj. 1908, *H. von Tuerckheim* (n. II. 2278).

Neotuerckheimia gonoclada Donn. Sm.—Folia singula cuspidato-acuminata deorsum attenuata. Pedunculi terminales 2–5-ni bracteis pluribus linearibus comitati. Corollae tubus late oblongus, limbus glanduloso-punctulatus.

Ramuli angulati, cortice exfoliato. Folia superiora approximata, inferiora internodiis 2–4^{cm} longis remota opaca 19–30^{cm} longa 5–7^{cm} lata, nervis lateralibus fortioribus utrinque 20–24, petiolis vix 2–3^{mm} longis crassis. Pedunculi 2.5–4^{cm} longi, bracteis 6–9^{mm} longis canaliculatis deciduis. Calyx 22^{mm} longus. Corolla 38^{mm} longa e schedula Tonduziana pallide flavicans, plica retroflexa 2.5^{mm} lata. Stamina 16–18^{mm} longa, loculis 4^{mm} longis. Discus 2^{mm} altus 4^{mm} latus. Ovarium 4^{mm} longum costis 8 angulatum, stylo 28^{mm} longo. Cetera desunt.

In silvis ad La Palma, Prov. San José, Costa Rica, alt. 1460^{m}, Sept. 1898, *Ad. Tonduz*, n. 7384 ex Pl. Guat. etc., quas ed. Donn. Sm. (n. 12563 herb. nat. Cost.). Sub *Crescentia* olim distributa.

Justicia (§TYLOGLOSSA Lindau) **multicaulis** Donn. Sm.—Folia inter minora rhomboideo- vel oblongo-ovalia vel lanceolata utrinque acuta. Flores axillares sessiles singuli vel subterminales et 2–4-ni interdum breviter spicati. Corollae tubus cylindricus limbo ampliato dimidio longior. Antherarum loculus inferior ab altero remotus appendicula ovali herbacea munitus.

Suffrutex nanus, caulibus e basi pluribus 25–33^{cm} longis, ramis herbaceis tetragonis bifariam pubescentibus lineolatis. Folia plerumque 15–32^{mm} longa 11–17^{mm} lata, interdum 34^{mm} longa 7^{mm} lata, cystolithis farcta praeter nervos subtus puberulos glabra, nervis laterlibus utrinque 4–5, petiolis bifariam puberulis 3–6^{mm} longis. Bracteae spatulato-obovatae 7^{mm} longae cum bracteolis linearispatulatis 5^{mm} longis herbaceae glabrae lineolatae. Calycis segmenta 5 linearia acuta 7^{mm} longa. Corolla 16^{mm} longa alba, tubo gracile 10^{mm} longo curvato, labio postico bidentato violaceo utrinque pubescente, antici paulo longioris lobis obovatis, intermedio maximo 4^{mm} longo atque lato. Stamina summis faucibus affixa 6^{mm} longa, antherarum loculo altero usque ad 0.5^{mm} inferius affixo perfecto.

Capsula oblonga acuminata 6^{mm} longa abortu disperma, retinaculis acutis, seminibus disciformibus rugosis alato-marginatis.—Corollae indole anormalis.

Ad ripas rivuli, Pansamalá, Depart. Alta Verapaz, Guatemala, alt. 1250^{m}, Jun. 1885, *H. von Tuerckheim*, n. 741 ex Pl. Guat. etc., quas ed. Donn. Sm. In silva montana prope Cobán, Depart. Alta Verapaz, Guatemala, alt. 1600^{m}, Jan. 1908, *H. von Tuerckheim* (n. II. 2091).

Ruprechtia (§ PSEUDOTRIPLARIS Benth.) **Kellermanii** Donn. Sm.—Folia subsessilia elliptica acuminata basi obtusiuscula subglabra minute inconspicueque reticulata. Racemi fasciculati, bracteis pedicellos superantibus. Perianthium fructiferum inter minora totum cinereo-atque-cano-sericeum, segmentis exterioribus linearibus, interioribus dimidio adnatis. Achenium substipitatum tenuiter elongato-conoidale.

Folia coriacea 11–13.5^{cm} longa medio 5.5–6^{cm} lata, venulis retiformibus tantum ope lentis manifestis et puberulis, petiolis vix 2^{mm} longis. Racemi fructiferi densiflori pilosi, rhachi 1.5–3.5^{cm} longa, bracteis orbiculari- vel oblongo-ovatis 5–6^{mm} longis fuscis puberulis, pedicellis 4^{mm} longis cano-pilosis prope apicem articulatis. Perianthii 18–21^{mm} longi tubus oblongus 7–9^{mm} longus, segmenta exteriora apice 3^{mm} basi 2^{mm} lata obscure trinervia et reticulata, interiorum pars libera 3^{mm} longa. Discus staminum sterilium 1^{mm} altus 9-denticulatus. Achenium 9^{mm} longum 2.5^{mm} latum in imam basin stipitiformem 1^{mm} longam angustatum prope apicem acute triquetrum et ciliatum ceteroquin rotundato-trilobum, lobis sulcatis glabris, stylis 1^{mm} longis stigmata acquantibus. Cetera desunt.—*R. Deamii* Robinson ejusdem loci incolae valde affinis.—Beato KELLERMAN[1] florae Guatemalensis exploratori indefesso dicata.

Gualán, Depart. Zacapa, Guatemala, alt 122^{m}, Dec. 1905, *W. A. Kellerman* n. 5985.—Typus in herb. Musei Nationalis servatur.

SPECIEM AMERICAE AUSTRALIS INCOLAM LICEAT HIC ADJUNGERE

Ruprechtia (§ PSEUDOTRIPLARIS Benth.) **colorata** Donn. Sm.—Folia oblongo-ovata vel -ovalia apice acuta vel obtusiuscula basi rotundata vel obtusa glabra subtiliter reticulata. Racemi singuli, pedicellis gracillimis. Perianthium fructiferum rubiginosum, segmentis exterioribus lineari-spatulatis glabrescentibus, interioribus liberis. Achenium lanceolatum acuminatum basi obtusum.

Arbuscula biorgyalis. Folia coriacea 8.5–12^{cm} longa 4–4.5^{cm} lata, venulis retiformibus non nisi oculo armato perspicuis, petiolis 3–4^{mm} longis. Racemi fructiferi solum visi sublaxiflori pubescentes, rhachi 2–4^{cm} longa, bracteis ocreatis apice ovatis 1.5–2^{mm} longis, pedicellis 5–7^{mm} longis medio articulatis. Peri-

[1] Obiit in Guatemala m. Mart. ann. 1908 febri confectus.

anthii 27–29^{mm} longi tubus obovatus 5–6^{mm} longus pubescens, segmenta exteriora apice 5^{mm} basi 2^{mm} lata pulchre trinervia et reticulata, interiora 4^{mm} longa. Discus staminum sterilium 0.5^{mm} altus 9-denticulatus. Achenium glabrescens 9^{mm} longum 3^{mm} latum triente superiore acute triquetrum inferne rotundato-trilobum, lobis leviter sulcatis, stigmatibus 2^{mm} longis stylos 3-plo superantibus. —*R. fuscae* Fernald et *R. Cumingii* Meisn. affinis perianthis etiam in sicco laete colorato insignis.

In collibus sabulosis prope litora oceani, Savanilla, Republica Colombiana, Febr. 1896, *J. Donnell Smith*.

Daphnopsis (§NORDMANNIA Benth. et Hook.) **monocephala** Donn. Sm.—Folia sessilia oblanceolata apice rotundata infra medium sensim attenuata supra glabrescentia subtus cano-sericea. Pedunculus subterminalis solitarius simplex gracilis cum capitulo unico cano-sericeus. Perianthium masculinum subsessile anguste infundibuliforme, lobis obtuse ovatis tubo 3-plo brevioribus intus glabris, squamulis 4 ovalibus.

Rami dichotomi ad apicem versus cano-villosi et confertim foliacei. Folia juniora utrinque villosa, provectiora (saltem superiora) 5–6.5^{cm} longa 1.5–2^{cm} lata coriacea, nervis lateralibus utrinsecus 5–6 longe ascendentibus et reticulis subtus prominulis, areolis pellucidis. Pedunculus infra gemmam apicalem ortus circiter 2^{cm} longus vel interdum abortu 5–7^{mm} longus, receptaculo convexo 3^{mm} lato 30–40-floro, pedicellis persistentibus obconicis circiter 1^{mm} longis. Perianthii masculini tubus 4.5^{mm} longus ore 1.5^{mm} latus, squamulis hypogenis rudimento pistilli glabro triplo brevioribus. Perianthium femininum ignotum.

El Rancho, Depart. Baja Verapaz, Guatemala, Jan. 1906, *W. A. Kellerman* n. 5714.—Typum in herb. Musei Nationalis vidi.

Euphorbia (§ALECTOROCTONUM Boiss.) **adinophylla** Donn. Sm.—Glabra. Folia in quoque verticillo indefinite compluria rhomboideo-elliptica apice obtusa vel rotundata basi acuta petiolos subaequantia. Cymae axillares et terminales corymbiformes petiolis subaequilongae. Involucrum graciliter pedicellatum, glandulis 5 appendice subcrenulata paulo angustioribus. Styli brevissime lobulati.

Fruticosa, ramis verticillatis sulcatis, internodiis 5–9^{cm} longis. Folia 6–16-verticillata 25–33^{mm} longa 14–18^{mm} lata, petiolis filiformibus 20–37^{mm} longis. Cymae obpyramidatae pedunculo 5–7^{mm} longo computato 22–36^{mm} longae 30–35^{mm} latae repetitus dichotomae, foliis floralibus oblanceolatis 3–7^{mm} longis, dichotomiis glandula magna instructis, axibus uti pedicelli 2–5^{mm} longi sulcatis. Involucri tubus campanularis 1.5–2^{mm} longus inferne sulcatus, lobi minuti obovati fimbriati, glandulae transverse ellipticae ab appendice arcuata margine liberae. Ovarium longe stipitatum, stylis indivisis 1.5^{mm} longis. Capsula ignota.—Ab *E. Schlechtendalii* Boiss. proxima differt foliis pro rata longioribus ad nodos con-

fertioribus, inflorescentia evoluta, pedicellis elongatis, stylis indivisis.—Ab incolis *Caraña* (Latine *Resina*) vocatur.

Republica El Salvador, loco natali haud accuratius addicto, ann. 1905, *Cárlos Rénson* (n. 187).—Typus in herb. Musei Nationalis servatur.

GUZMANIA BRACTEOSA André.—Folia auctoribus adhuc ignota linearia 30–55^{cm} longa acute attenuata medio 13–25^{mm} lata in vaginam 25–50^{mm} latam sensim dilatata tenuiter coriacea utrinque praesertim subtus pallide lepidota vel glabrescentia, nervis crebris utrinque prominentibus.

In silvis ad Las Vueltas, Tucurrique, Costa Rica, alt. 635^{m}, Mart. 1899, *Ad. Tonduz* (n. 13291).—Epiphyta (ex cl. repertore) in silvis montanis prope Purulá, Depart. Baja Verapaz, Guatemala, alt. 1800^{m}, Apr. 1907, *H. von Tuerckheim* (n. II. 1826).

BALTIMORE, MARYLAND

COMPARATIVE HISTOLOGY OF FRUITS AND SEEDS OF CERTAIN SPECIES OF CUCURBITACEAE

KATE G. BARBER

(WITH FIFTY-THREE FIGURES)

Introduction

This investigation was undertaken with the view to supplementing the work already done on the histology of the fruits and seeds of Cucurbitaceae. The literature, although not meager, treats only of the most conspicuous elements of the spermoderm, ignoring, with a few exceptions, the less important tissues of the seed and the whole of the pericarp.

In the following paper are included additions to the histology of the spermoderm and new descriptions of the pericarps of the common species; also brief descriptions of six interesting seeds previously undescribed.

I wish to acknowledge my great indebtedness to Dr. A. L. WINTON, under whose guidance and inspiration this work was carried on, and also to Professor A. W. EVANS for advice in its preparation.

Résumé of the literature

In 1833 BISCHOFF[1] published two cuts showing cross-sections of the seed coats of *Cucurbita Pepo* and *C. Lagenaria*, which, according to FICKEL,[2] leave much to be desired with regard to detail.

VON HÖHNEL[3] was the first to publish a detailed description of the seed coats of the Cucurbitaceae, the species studied being *Cucurbita Pepo* L., *Lagenaria vulgaris* Ser., and *Cucumis sativus* L.

A thorough investigation of the integuments, from before fertilization of the flower until maturity, led him to conclude that: (1) the inner integument (three to four layers thick) develops but slightly, becoming the collapsed, thin-walled inner parenchyma of the seed

[1] Handbuch der bot. Terminologie und Systemkunde. *pl. 43. figs. 1872, 1873A.*

[2] Ueber die Anatomie und Entwickelungsgeschichte der Samenschalen einiger Cucurbitaceen. Bot. Zeit. **34**:738. 1876.

[3] Morphologische Untersuchungen über die Samenschalen der Cucurbitaceen und einiger verwandter Familien. Sitzb. Akad. Wiss. Wien, Mathem.-Naturw. **73**:297. 1876.

coat; and (2) the outer integument (eight to ten layers thick) forms the greatly differentiated outer layers of the coat.

At maturity he found that the spermoderm consists of a complicated structure with five distinct tissues, namely: (1) inner epithelium of the carpel; (2) outer and (3) inner integument; (4) perisperm; and (5) endosperm. These five in turn are subdivided into ten layers, each one to many cells thick. About the edge of the seed, between the fifth and sixth layers, runs the small raphe.

This author divided the family into two large groups. In the first belong those seeds with the epithelium of the carpel firmly attached to the spermoderm, represented in his work by *Cucurbita Pepo* and *Lagenaria vulgaris*. The second includes the species without this epithelium, illustrated by *Cucumis sativus*. Otherwise there are no great differences in development.

In the same year, one month after the appearance of VON HÖHNEL'S paper, FICKEL[2] published his inaugural dissertation, describing the seed coats of *Cucumis sativus* L., *C. Dudaim* L., *C. myriocarpus* Naud., *Cucurbita Pepo* L., *C. melanosperma* A. Br., *Lagenaria vulgaris* Ser., *Citrullus vulgaris* Schrad., *Benincasa cerifera* Savi., *Bryonia alba* L., *B. dioica* L., *Ecballium agreste* Rchb., *Sicyos angulatus* L., *Cyclanthera explodens* L., *C. pedata* Schrad., and *Bryonopsis erythrocarpa*. He gives descriptions and cuts of the mature seed coat and its development from the two integuments, and reaches the following conclusions: (1) the seed coat has five layers; (2) the epidermal cells are radially elongated and, with the exception of those of Sicyos and Cyclanthera, have thickenings of various kinds on the radial walls; (3) the second layer consists of one or more layers of cells varying in size and thickness of walls; (4) a third layer has either radially or longitudinally elongated cells; and (5) the remaining layers are of compressed cells without definite structure.

GODFRIN[4] briefly notes the seed coats of *Cucumis sativus* L., *Cucurbita maxima* Duch., *Lagenaria vulgaris* Ser., *Sicyos angulatus* L., and *Cyclanthera pedata* Schrad. In his general description the spermoderm is represented as having six layers, as follows: (1) epidermis of prismatic cells; (2) small cells differing as to number, size, and

[4] Etude histologique sur les téguments séminaux des angiospermes. Soc. Sci. Nancy **1880**: 160.

thickness of walls; (3) a single layer of sclerenchymatized cells varying but slightly in all the species; (4) outer and inner parenchyma; (5) inner epidermal cells, often separated from the preceding layer by longitudinally elongated cells; and (6) inner row of thick-walled cells with granular contents, the author evidently including the endosperm in the spermoderm. This is followed by a description of each of the species already mentioned.

VON HÖHNEL's division of the family into two groups, distinguished by the presence or absence on the spermoderm of the inner carpellary layer, is criticized, as GODFRIN always found this layer present in fresh material. He used the following grouping, based on the elongation of the cells of the "protective" (third) layer: (1) tangentially elongated cells (Cucumis, Lagenaria, Cucurbita, Citrullus); and (2) radially elongated cells (Sicyos and Cyclanthera). The individual descriptions are brief, many details being omitted.

FISCHER[5], in his classical work on sieve tubes of the Cucurbitaceae, describes a detailed study of the elements in all parts of the plant. The tubes are of four kinds: (1) bundle sieve tubes (usual type found in fibro-vascular bundle); (2) ectocyclic (isolated tubes of hypoderm); (3) entocyclic (isolated tubes of the inner tissues); and (4) commisural (connecting those of the bundle with the isolated tubes). In the young isolated tubes the contents are thickened but in the old there is a watery slime secreted by the neighboring cells. These isolated tubes, being free from callus plates, were mistaken by earlier writers for latex tubes.

Six plates are given illustrating these tubes in *Cucurbita Pepo*, *Lagenaria vulgaris*, *Sicyos angulatus*, *Cyclanthera pedata*, *Melothria pendula*, *Bryonia alba*, and *Luffa pentandra*.

T. F. HANAUSEK[6] gives chemical analyses of *Cucumis sativus* L., *C. Melo* L., *C. Citrullus* L., *Cucurbita Pepo* L., and *C. maxima* Duch., and mentions briefly the histology of each.

HARZ[7] describes and illustrates cross-sections of species of Cucumis, Citrullus, Lagenaria, and Cucurbita. The numerous species are divided into races, varieties, and subvarieties, with long lists of syno-

[5] Untersuchungen über das Siebröhren-System der Cucurbitaceen. Berlin. 1884.

[6] Die Nahrungs- und Genussmittel aus dem Pflanzenreiche 195. Kassel. 1884.

[7] Landwirthschaftliche Samenkunde 767. Berlin. 1885.

nyms under each. The author briefly notes the macroscopic appearance of the fruit, then gives short histological descriptions of the seed. According to his division the spermoderm has five layers. Some of the details of structure of the outer layers, and nearly all of the inner ones, are omitted.

VOGL[8] devotes but a single paragraph to a microscopical description of Cucurbitae.

BRAEMER[9] in 1893 studied the stem, leaf, pericarp, and seed of *Bryonia dioica* Jacq., *Ecballium Elaterium* Rich., and *Citrullus Colocynthis* Schrad., but confined his attention chiefly to a microchemical investigation of the contents of the sieve tubes and latex tubes, both of which he regards as latex tubes, accepting the descriptions of the tissues given by earlier writers. According to his introduction, the pericarp has an outer and inner epidermis with a sarcocarp between. Within the spermoderm, having hard and lignified layers, are inclosed an embryo, reduced to a small radicle and two cotyledons, rich in oil and aleurone grains, and the remains of the perisperm and endosperm.

The main part of the paper is devoted to the long, ramifying, straight or sinuous tubes containing a yellow semi-fluid, finely granular, refractive substance which entirely fills the cavity. Both lateral and cross walls are composed of cellulose without any indications of sieve or callus plates. In their morphological and chemical characters they resemble the latex tubes of Convolvulaceae and Campanulaceae, and the isolated sieve tubes of FISCHER. In these tubes BRAEMER found the three "active principles" bryonin, colocynthin, and elaterin.

PLANCHON and COLLIN[10] treat the species used as drugs. Macroscopic and microscopic sections are figured, but no histological details are given, of the fruits and seeds of *Cucurbita Pepo* Duch., *Citrullus Colocynthis* Schrad., *Cucumis sativus* L., *Ecballium Elaterium* Rich., and Fevileae.

VILLIERS and COLLIN[11] use the bicollateral bundles and sieve

[8] Pharmakognosie 196. Wien. 1892.

[9] De la localisation des principes actifs des Cucurbitacées. Toulouse. 1893.

[10] Les drogues simples d'origine végétale **2**:292. Paris. 1896.

[11] Traité des altérations et falsifications des substances alimentaires 454. Paris. 1900.

tubes (or latex tubes) in the detection of pumpkin pulp as an adulterant of preserves. They have an original cut, but their description of these elements is taken from FISCHER[5] and BRAEMER.[9]

T. F. HANAUSEK[12] gives one figure illustrating the characteristic elements of the seed of *Cucurbita Pepo* L., *C. maxima* Duch., and *C. moschata* Duch. These elements are the *Skleriden* (resembling the epidermis of Spanish pepper), spongy parenchyma, starch grains of the inner parenchyma, endosperm and cotyledon tissue with aleurone grains.

ARTHUR MEYER[13] refers briefly to the aleurone grains of *Cucurbita Pepo* as having a diameter of 1–4 μ (mostly 3 μ) and small crystalloids. In his table taken from LUDTKE,[14] the seeds of Citrullus and Colocynthis are stated to contain numerous aleurone grains 1–7.5 μ in diameter, each having one globoid (0.5–1 μ) and one crystalloid (1–3 μ).

BÖHMER[15] gives a chemical analysis of the seeds of the Cucurbitae and one figure showing a cross-section and surface view. His brief histological description is taken from other authors.

COLLIN and PERROT[16] describe briefly and give a cross-section of the seed of *Cucurbita Pepo* Duch.

According to MOELLER[17] the fruits of Cucurbitaceae are all large berries with hard shells, soft fruit-flesh, and many seeds. The seed coat is divided into four tissues: (1) palisade cells with thickenings on radial walls; (2) stone-cell layer; (3) stellate parenchyma; and (4) thin-walled parenchyma. A brief description follows of *Cucurbita Pepo* L., *C. maxima* Duch., *C. moschata* Duch., *Cucumis sativus* L., *C. Melo* L., and *Citrullus vulgaris* Schrad., with cuts of the last two.

[12] Lehrbuch der technischen Mikroskopie 370. Stuttgart. 1901. Translation, WINTON, The microscopy of technical products 369. New York. 1907.

[13] Die Grundlagen und die Methoden für die mikroskopische Untersuchung von Pflanzenpulvern 32. Jena. 1901.

[14] Ueber die Beschaffenheit der Aleuronkörner einiger Samen. Ber. Deutsch. Pharm. Gesells. **1891**:56–59.

[15] Die Kraftfuttermittel, ihre Rohstoffe, Herstellung, Zusammensetzung, Verdaulichkeit und Verwendung, mit besonderen Berücksichtigung der Verfälschungen und der mikroskopischen Untersuchung 508. Berlin. 1903.

[16] Les résidues industriels 270. Paris. 1904.

[17] Mikroskopie der Nahrungs- und Genussmittel 470. 2. Aufl. Berlin. 1905.

BARBER,[18] in a chapter on Cucurbitaceae, gives brief descriptions of *Cucurbita Pepo* L., *C. maxima* Duch., *Cucumis sativus* L., *C. Melo* L., and *Citrullus vulgaris* Schrad., illustrating the first-named species by three original cuts.

Geographical distribution

The Cucurbitaceae are scattered over the greater part of the earth's surface, but reach their highest development in the tropics. Representatives are, for the most part, absent in the colder regions of the temperate zone, the two exceptions being *Sicyos angulatus*, found in Canada, and *Echinocystis lobata* in New England.

The total number[19] of genera is eighty-five, the Old World claiming fifty-four and the western hemisphere thirty-eight, while seven are common to both. Under each there are long lists of species, subspecies, and varieties, authors differing greatly as to the number.

EDIBLE SPECIES.—Many species have long been cultivated for food. Probably one of the oldest on record is Citrullus (watermelon), a favorite with the ancient Egyptians. Other important species are *Cucumis sativus* (cucumber), eaten in China as a vegetable more than two centuries before the Christian era; *Cucurbita Pepo* (pumpkin), grown by the aborigines in America; and *Cucumis Melo* (musk melon), greatly prized in Asia and Africa. These have now spread to all the warmer regions of the earth.

ORNAMENTAL SPECIES.—There are many varieties grown for the curious form and vivid coloring of the fruit, among which are *Momordica balsamina* (balsam apple), *Lagenaria vulgaris* Ser. (common gourd), *Cucumis erinaceus* (hedge-hog gourd), *Cyclanthera explodens* (squirting cucumber), and *Luffa cylindrica* (dish-cloth gourd).

PHARMACEUTICAL SPECIES.—Among those used for drugs, both here and in Europe, are *Bryonia dioica* (bryony), *Citrullus Colocynthis* (colocynth), and *Ecballium Elaterium* (elaterin).

General characters

MACROSCOPIC

FLOWER.—The axillary flowers, yellow or white in color, are borne either solitary or in groups of various kinds. They are usually

[18] In WINTON, Microscopy of vegetable foods 401. New York. 1906.

[19] ENGLER UND PRANTL, Pflanzenfamilien IV. 5:9.

monoecious, epigynous; calyx and corolla actinomorphic, adnate at the base. The stamens are five in number, four of which frequently cohere in pairs, or more rarely they all unite to form a column. The ovary is one- to five-, usually three-celled.

FRUIT.—In the Cucurbitaceae are found the largest fruits of the whole plant kingdom. From the enormous berry of Cucurbita, reaching a maximum of several kilos in weight, there are all gradations down to the small burr of *Sicyos angulatus*, only slightly larger than the single inclosed seed.

The fruits are nearly always fleshy berries; they may, however, become membranaceous and dry, preserving at the same time their original shape. There is no characteristic form for the family, the shape differing as much as the size. All possible variations of spherical, elliptical, greatly elongated, and curious unsymmetrical forms are represented. They are smooth, warty, or covered with spines, or various other kinds of emergences. In addition to these outgrowths, the young fruits of all the common species bear one or more forms of hairs which, in most cases, persist at maturity. The color varies from white, green, and yellow to red, with spots and stripes on some of the varieties.

All the fruits described in this paper are indehiscent with the exception of Echinocystis, which bursts irregularly at the top.

The pericarp, or rather the pericarp and adherent receptacle, varies in thickness (thin or thick rind, or solid fruit-flesh), color (white, green, yellow, or red), and texture (watery or dry, sclerenchymatized or soft). The central placentae extend to the outer wall and divide, turning back so as to give a parietal appearance.

SEED.—The seeds, borne either singly or in great numbers, are anatropous, large, ovate, and flattened, with or without a border (formed by elongated epidermal cells) on each side at the edge. They vary in shape from the narrow and pointed to the broad, rounded, or rectangular forms, and in color from white to brown and black.

MICROSCOPIC

PERICARP.—The pericarp may be divided into six, more or less distinct tissues as follows:

1. *Epicarp.*—The cells are for the most part polygonal, forming

a palisade layer, those about the stomata being frequently elongated. The outer and radial walls are cuticularized and occasionally colored.

2. *Hypoderm.*—Few or many layers of isodiametric cells form the tissue beneath the epicarp. The cells are somewhat thickened and occasionally pitted.

3. *Outer mesocarp.*—Isodiametric cells with either cellulose, or sclerenchymatized and pitted, walls (stone cells, etc.) form a sharply defined zone varying from a few to many cells in thickness.

4. *The middle mesocarp* consists of large, usually isodiametric, thin-walled cells, often turgid with a watery cell sap and containing a small amount of starch. The starch grains are small, with an average diameter of 10 μ. They are truncated, frequently occurring in aggregates of two and three, with slightly eccentric hilum and faint rings. Polarization crosses are very distinct.

5. *Inner mesocarp.*—Several layers of thin-walled cells, forming this tissue, closely resemble the preceding layers. The cells are small and have no visible contents.

6. *Endocarp.*—Very small, thin-walled, tangentially elongated cells, arranged side by side in groups, form a thin transparent tissue. With the exception of Cucumis, this layer remains so firmly attached to the dry seed that some authors describe it as the outer layer of the spermoderm.

The anastomosing *bundles* occurring throughout the mesocarp are bicollateral. They are either small and soft, or large and stiff, forming a conspicuous network. The elements consist of spiral, annular, and reticulated vessels, and sieve tubes having large sieve plates evident without staining.

Isolated sieve tubes and latex tubes.[20]—FISCHER[5] claims there are no true latex tubes, those known by this name being simply sieve tubes that have ceased to function; BRAEMER[9] and other later authors, however, use the term "latex tubes." I have seen the per-

[20] According to DE BARY (Comparative anatomy of the vegetative organs of the phanerogams and ferns 198. Oxford. 1884) DIPPEL finds the septa and lateral walls of articulated tubes provided with sieve plates and thinks them intermediate between sieve tubes and latex tubes. DE BARY himself finds not the plates but perforations scattered over the whole wall, and further states that there are two kinds of latex tubes which do not correspond in function: (1) those secreting tannin, etc., and (2) those (of milky plants) which are closely related to sieve tubes.

forated plates in some tubes and have not found them in those containing granular milky contents which harden in alcohol, therefore shall mention both in the following descriptions. These elements occur in considerable numbers throughout the middle tissues of the pericarp.

Each seed has a firm spermoderm of many layers, a thin collapsed perisperm and endosperm, and a large embryo consisting of two large, flat, leaf-like cotyledons and a small radicle.

SPERMODERM.—Authors variously state the number of layers in this leathery coat or shell as four[17] to ten.[21] I myself consider it as consisting of five distinct tissue layers, the second being occasionally differentiated into two, and the fourth often into two or three forms of cells arranged in as many layers. It is developed from the two integuments (*fig. 10*), the outer integument forming the three outer and part of the fourth layers, the remainder of the coat developing from the inner integument.

1. *The epidermis* consists of a single layer of prismatic palisade cells, polygonal in surface view. They are usually of equal height over the flat surface of the seed, increasing in height at or on both sides of the edge. The radial walls of a few species (as *Echinocystis lobata*) are uniformly thickened; in all the other seeds they have either straight or branched thickenings running from the inner to the outer tangential walls. The outer walls, and frequently the inner, are thickened.

VOGL,[8] the only author that notes the presence of starch in this layer, gives no description of the grains. According to my own observation they are small, globular, reaching a maximum diameter of 7 μ, the larger ones showing a central hilum but no rings. They polarize very indistinctly.

2. *Subepidermal layer.*—One or more layers of sclerenchymatized cells, varying greatly in size and shape, make up this layer. The cells are either small, pitted, without intercellular spaces (Cucurbita), or longitudinally elongated, arranged end to end in rows, with numerous characteristic intercellular spaces (Cucumis), or form a thick layer of greatly thickened irregularly arranged cells. No contents are evident.

3. *Sclerenchyma.*—This consists of a layer of exceedingly thick-

[21] ENGLER UND PRANTL, Pflanzenfamilien IV. 5:8.

walled cells elongated either tangentially and arranged end to end in longitudinal rows, or radially forming a palisade layer. The walls are sinuous with numerous pits, and after maceration the margins of the outer and inner tangential walls are seen to be lobed, each lobe branching with the ends overlapping and fitting together to form a flat compact layer (*fig. 18*). The empty cell cavities are comparatively small and present a striking oval appearance in median section.

4. *Parenchyma.*—Many cell layers of spongy parenchyma, differing greatly in size and shape, make up this layer. The cells of the outer layers are usually small and frequently sclerenchymatized and pitted. Within these small cells are one or more layers of either large or small stellate cells having very large intercellular spaces. Their thin walls are usually sclerenchymatized and often pitted or reticulated (Cucurbita). The remaining layers consist of small, thin-walled spongy parenchyma cells containing chlorophyll in some species.

The small raphal bundles are found imbedded in this parenchyma usually about the edge only; a few exceptions, however, show branches on the flattened surface of the seed.

5. *Inner epidermis.*—A single layer of small, polygonal, and inconspicuous thin-walled cells forms the inner tissue.

PERISPERM.—This thin coat is collapsed in the mature fruit, but treatment with Javelle water brings to view several layers of small, very thin-walled cells covered with an epidermis having cuticularized outer and radial walls. No contents are evident.

ENDOSPERM.—This consists of one layer of very thick-walled polygonal cells, containing oil and protein granules. A few exceptions (as *Citrullus vulgaris*) have within this layer several more layers of empty thin-walled cells.

EMBRYO.—The leaf-like cotyledons have an epidermis of small cells below which, on the inner side, are two sharply defined palisade layers. Procambium bundles run through the small-celled mesophyll. All of the cells are filled with oil and protein granules containing globoids and crystalloids which are very minute and of practically no diagnostic importance.

Specific characters

CUCURBITA PEPO L.

Cucurbita Pepo L. (pumpkin), according to the earlier writers, was introduced from southern Asia, but WITTMACK, in his recent investigations of prehistoric remains in Peru, claims it to be a native of America. Early explorers also recorded the cultivation of this fruit by the aborigines in their maize fields.

The fruit is one of the largest of the Cucurbitaceae, occasionally reaching a weight of 200 kilos. It is a smooth, apple-shaped berry, with about twenty, more or less pronounced, longitudinal grooves, the color varying from yellowish green to orange. There are many subspecies, differing greatly in size and shape, of which HARZ enumerates thirty. Among them are the small to enormously large spherical, ellipsoidal, flask-, egg-, J-, and curiously-shaped forms. Most of the larger ones are cultivated for food, the smaller as ornamental fruits.

At maturity the fruit consists of a hollow, yellow rind, 2–3^{cm} in thickness, containing a tangle of slimy fibers, among which are the numerous flattened seeds.

The white seeds (*fig. 1*) are 1.5–2.5^{cm} in length, elliptical, flattened, and have a narrow border about the edge on both sides.

FIG. 1.—*Cucurbita Pepo* L. Seed. ×1.

PERICARP.—This makes up the bulk of the fruit. It includes the rind and fibers, the connecting parenchyma breaking down before the fruit reaches maturity.

1. *Epicarp* (*figs. 2, 3, epi*).—The prismatic cells form a palisade layer about 50μ in height, with outer and radial walls greatly thickened, cuticularized, and colored bright yellow. In surface view they are polygonal (14 μ in diameter), except at characteristic white spots about which they are elongated and curved. These white spots consist of a stoma of the common type, from which radiate rows of tangentially elongated epidermal cells. The stomata are not uniformly distributed and occasionally two are found in the same group of radiating cells.

On the very young fruit, even before the fertilization of the ovary, two forms of hairs are found (*fig. 3*). Both arise from a foot-cell differing from the neighboring epidermal cells only in the more

rounded shape. The hairs dry up and disappear while the fruit is still very small, leaving the foot-cell intact. Later the epidermal cells divide, thicken their walls, and press against the foot, which thus becomes polygonal. As both kinds of cells are of the same size, the two are indistinguishable, which accounts for the absence of hair scars on the mature fruit.

The first form of hair is jointed (l^1) and of great size, often reaching a length of 1.5–2^{mm}. The diameter increases rapidly (up to about 85 μ) for a short distance from the foot, then gradually tapers, forming a long, thick-walled (5 μ), conical hair. The first few cells

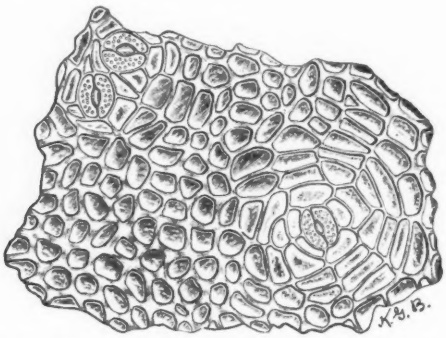


FIG. 2.—*Cucurbita Pepo* L. Epicarp in surface view. ×320.

are two or three times as broad as long, while the following cells become elongated as the hair increases in size.

The second form is capitate (l^2), and like the first increases in diameter from the foot, forming a jointed stalk of four or five cells. It ends with a large spherical head of one or more cells, often 54 μ in diameter.

2. *Hypoderm.*—Many cell layers of exceedingly small, isodiametric cells, 20 μ in diameter, form this layer. The cells have thick walls, occasional pits, and small intercellular spaces. The visible contents consist of numerous protein granules. This layer closely resembles the corresponding one of *C. Pepo* var. *verrucosa* Naud. (*fig. 7, hy*).

3. *Outer mesocarp.*—Within the preceding layer is a region composed of cells graduating in size from the small cells of the hypoderm

to the large ones of the middle mesocarp. They are isodiametric, have thick walls and intercellular spaces, and but few contents.

4. *Middle mesocarp* (*fig. 4*).—In this layer the cells become gradually larger, thicker-walled, and more loosely arranged. They contain small starch grains (*am*), reaching a maximum size of 10 μ. The outer cells contain a considerable number of these grains, but the increase in size of the cells is accompanied by a decrease in amount of starch.

5. *Inner mesocarp.*—This layer consists of rather large-celled parenchyma with no evident contents.

Bundles and isolated sieve tubes, together with anastomosing latex tubes (*lat*) are found throughout the mesocarp, while in the center of the fruit there is a great mass of tough fibers, surrounded by the remains of the broken-down parenchyma.

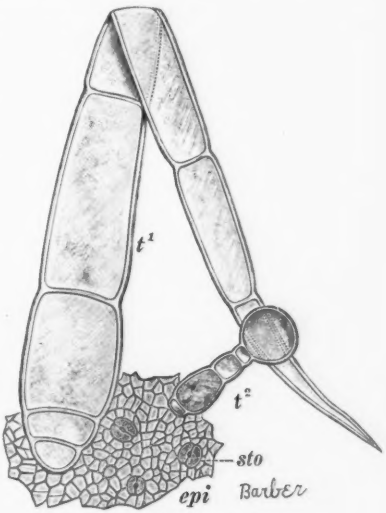


FIG. 3.—*Cucurbita Pepo* L. Immature epicarp in surface view; *epi*, epicarp with t^1, jointed conical hair, t^2, capitate hair, and *sto*, stoma. ×160.

6. The *endocarp* appears on the seeds as a thin membrane of longitudinally elongated cells, arranged end to end in rows. The inner wall is about the same thickness as the outer wall of the epidermis of the spermoderm, to which it is quite firmly attached; from the dry seeds, however, it may be readily separated as a thin, transparent, colorless skin.

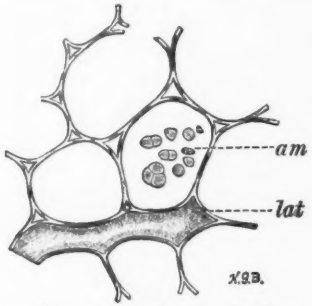


FIG. 4.—*Cucurbita Pepo* L. Cross-section of mesocarp showing *am*, starch grains, and *lat*, latex tube. ×160.

SPERMODERM (*figs 5, 6*).—The five layers making up the spermoderm are as follows:

1. *Epidermis* (*ep*).—The prismatic cells form a continuous layer without intercellular spaces. They are radially elongated, on the flat side of the seed to 270 μ, on the edge to 50 μ, while the border consists of a ridge of cells several times as high as those of the flattened surface. The outer wall is thickened, but has no cuticle, and the radial walls are very thin, with peculiar branching thickenings of cellulose. The thickenings run from the base of the cell, one on each wall, as single straight rods until near the outer wall, where they branch pro-

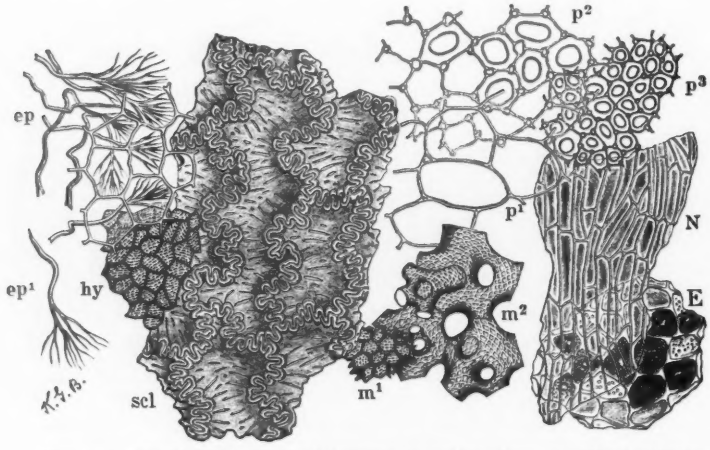


FIG. 5.—*Cucurbita Pepo* L. Seed elements in surface view; *ep*, ribbed palisade cells of epidermis; *ep*¹, isolated rib; *hy*, subepidermal layer; *scl*, sclerenchyma; *m*¹, pitted parenchyma; *m*², reticulated spongy parenchyma; *p*¹, parenchyma; *p*², spongy parenchyma; *p*³, inner epidermis of spermoderm; *N*, perisperm; *E*, endosperm. ×160.

fusely, giving rise to a beaded appearance in tangential section. After maceration, or in scrapings of the spermoderm, the rods fall upon their sides, presenting the appearance shown in *fig. 5*, *ep*¹. In dry seeds the walls of this layer are frequently broken down, and only a few of the thickenings remain, which may be mistaken for the cut surface of the walls themselves.

Round starch grains (*am*), up to 7 μ in diameter, of the type already described, occur in considerable numbers in the epidermal cells.

2. *Subepidermal layer* (*hy*).—Below the epidermis is a layer of

small, polygonal, somewhat elongated cells, about 25 μ in diameter, with numerous minute pits, giving the walls a beaded appearance. This layer, without intercellular spaces, is three to five cells thick, the number increasing toward the edge of the seed.

3. *Sclerenchyma* (*scl*).—Firmness is given to the spermoderm by one layer (over the edge two or three) of longitudinally elongated (250 μ) cells, arranged end to end in rows. In surface view, both side and end walls are sinuous, often reaching 20 μ in thickness. After maceration and by careful focusing, the outer and inner surfaces of these cells may be seen to send out remarkable ramifications, whose dichotomous branches overlap one another. In transverse section the oval appearance of the cell cavity is a characteristic feature. A few pits may be seen with a high power.

4. *Parenchyma*.—There are three quite distinct layers, the parenchyma showing the greatest differentiation in this species. In contact with the sclerenchyma is the first layer of small pitted cells, with few or no intercellular spaces (m^1). Resting on this compact layer, either singly or in groups, are larger cells, which stand out like branches in the intercellular spaces of the next layer.

The cells of the second layer are characteristic of the genus (m^2). In this species the layer is two cells thick, with intercellular spaces so large that they form a great cavity in which the cells are suspended. In form the cells are somewhat stellate, joining the preceding layer by one branch or a similar but smaller cell. The walls are beautifully reticulate, the thickenings following a definite course around the curved surface of the cell. The cross walls are netted in a similar manner but with a somewhat larger mesh.

The true spongy parenchyma consists of a number of layers of somewhat collapsed cells, but treatment with Javelle water expands the tissues so that they may be easily studied. The cells are thin-walled, decreasing in size toward the inner epidermis (p^1, p^2). In surface view the contour of the branches appears, in the center of the cells, as rings nearly as large as the cells themselves. A green color is given to these inner layers by chlorophyll.

5. The *inner epidermis* (p^3) is composed of small, thin-walled cells.

PERISPERM (*figs. 5, 6, N*).—In this coat there are about six layers

of thin-walled cells with longitudinally elongated, cuticularized, epidermal cells.

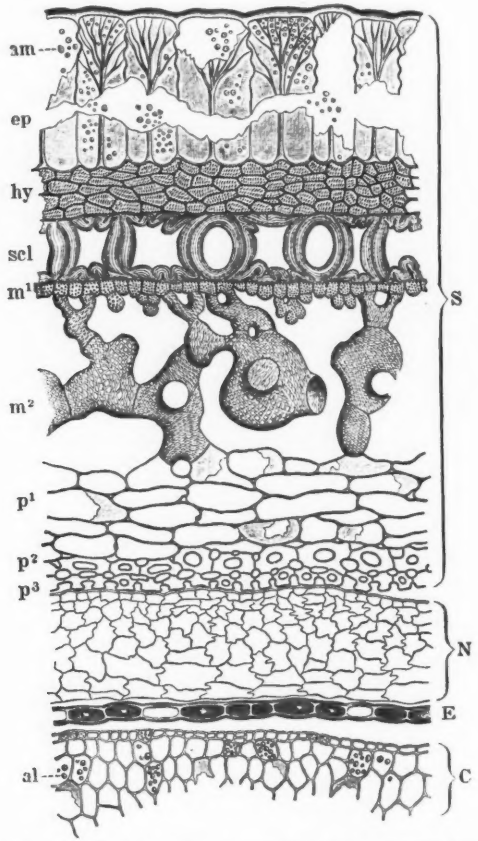


FIG. 6.—*Cucurbita Pepo* L. Seed in cross-section; *S*, spermoderm consisting of *ep*, ribbed palisade cells of epidermis containing *am*, starch grains, *hy*, pitted subepidermal layer, *scl*, sclerenchyma, m^1, pitted parenchyma, m^2, reticulated spongy parenchyma, p^1, parenchyma, p^2, spongy parenchyma, and p^3, inner epidermis; *N*, perisperm; *E*, endosperm consisting of aleurone cells; *C*, cotyledon containing *al*, aleurone grains. ×160.

ENDOSPERM (*figs. 5, 6, E*).—This consists of a single layer of cells with thickened walls, containing granular protoplasm and a large central nucleus.

EMBRYO.—The cotyledons (*C*) have small epidermal cells on both surfaces and two layers of palisade cells within the inner epidermis. Aleurone grains (*al*) up to 6 μ, containing globoids and crystalloids, also oil, are found in all the cells.

C. PEPO VAR. VERRUCOSA NAUD.

This variety, the crook-necked squash, has a rather large flask-shaped fruit, with the neck showing a distinct curve or crook. Longitudinal grooves occur frequently, but are not so well marked as in *C. Pepo*. There is a hard rind, yellow or orange in color, covered with very pronounced warts and filled with bundle fibers. The central parenchymatous tissue breaks down only in the swollen base, the neck not expanding enough to tear the tissues apart.

The seeds, of a dirty white color, are not over 2^{cm} long, smooth, and flattened, with a border at the edge.

PERICARP (*fig. 7*).—The pericarp of this variety differs very little from that of *C. Pepo*, the chief difference being in the greater hardness of the rind.

1. *Epicarp* (*epi*).—The palisade layer is about 36 μ in height, the thickened, prismatic cells having cuticularized outer and radial walls. The outer wall is not uniformly thickened; instead it has a depression over each cell, giving it a wavy contour in cross-section.

There are two forms of hairs, resembling those of *C. Pepo* in size and shape; instead of falling off, however, they persist on the mature fruit. Sunken stomata (*sto*) are present in considerable numbers.

2. *Hypoderm* (*hy*).—The cells of this layer resemble those of *C. Pepo*, the description given for that species applying to this.

3. *Outer mesocarp* (*st*).—This characteristic layer consists of many layers of stone cells which differ considerably in size. The cells are polygonal, small in the sharply defined outer layer, increasing in size inward until they are lost in the next cell layer. About spherical cavities (*x*), occurring at the junction of this layer with the hypoderm, the cells elongate radially to about twice their transverse diameter. These cavities are really large intercellular spaces appearing in the young fruit and showing no evidence of secreting cells in any stage of growth. Before the walls thicken the cells bulge out into these cavities. Among the smaller polygonal cells are also large spherical

ones with cell cavity, frequently 150 μ in diameter, about the size of the intercellular cavities, both being conspicuous. The cell walls vary from 8–14 μ in thickness and have numerous pits.

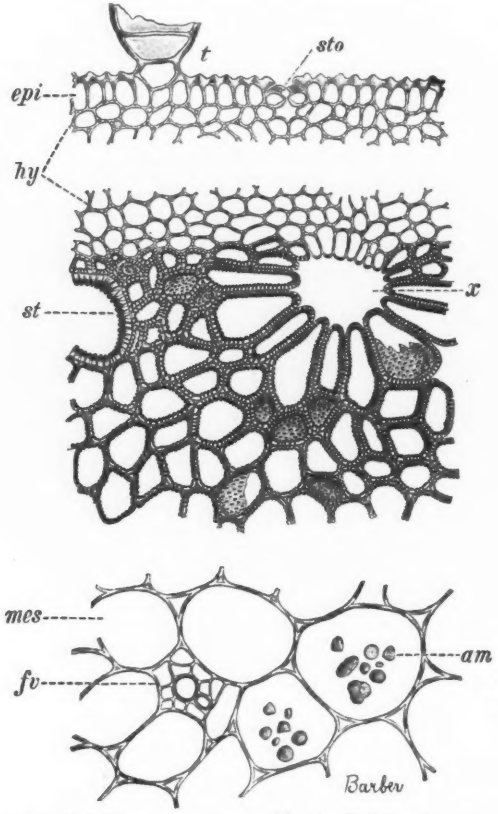


FIG. 7.—*Cucurbita Pepo* var. *verrucosa* Naud. Pericarp in cross-section; *epi*, epicarp with *t*, hair, and *sto*, stoma; *hy*, hypoderm; *st*, outer mesocarp (stone-cell layer) with *x*, spherical cavity; *mes*, middle mesocarp with *fv*, bundle, and *am*, starch. ×160.

4. *Middle mesocarp* (*mes*).—The middle layers of the mesocarp consist of rather thick-walled cells containing numerous truncated starch grains (*am*).

5. *Inner mesocarp.*—The cells of the inner layers are the same size as those of the middle mesocarp, but have thinner walls, larger intercellular spaces, and no evident contents. The fibrovascular bundles, sieve tubes, and latex tubes, found throughout the tissues, are of the usual type.

6. *Endocarp.*—This layer corresponds with that of the species already described.

SPERMODERM.—This differs from that of *C. Pepo* only in the first and fourth layers, as follows:

1. *Epidermis.*—The thickenings on the radial walls, besides branching profusely at the outer end, send out occasional fine branches the whole length of the rod.

4. *Parenchyma.*—The second layer of this parenchyma is four or five cells thick, with somewhat smaller intercellular spaces than in *C. Pepo.*

C. PEPO VAR. MELOPEPO L.

The popular name (scallop) for this variety suggests the shape of the fruit. It is a large depressed berry with ten to fifteen quite deeply cut longitudinal grooves. Like *C. Pepo* it is firm, smooth, and yellow, with a rind and a central cavity containing fibers.

The seeds are elliptical, 1–1.5^{cm} in length, smooth, flattened, bordered, and of a yellow-white color.

PERICARP.—The cell structure does not differ essentially from that of *C. Pepo.*

SPERMODERM.—This coat differs slightly from the corresponding coat of *C. Pepo.* The palisade layer, with thickenings like those of the variety *verrucosa*, is thicker, reaching 0.3^{mm} on the flattened surface of the seed.

The *raphe*, which in the species previously described is found only around the edge of the seed, here sends out a few branches over the sides. In cross-section the cut surfaces of these branches are quite evident in the inner parenchyma.

C. PEPO VAR. OVIFERA NDN.

The fruit of this variety is egg-shaped, 8–10^{cm} long, of a yellow-white color, with hard rind which dries up and persists in its original

form. The rind is 1^{cm} thick surrounding the central mass of fibers, which do not break down. A cavity is formed, but it is not so evident as in the other species of this genus, since the tissues, although separating, retain their original position.

The seeds are of the usual type for this genus.

PERICARP.—The layers are essentially like those of the variety *verrucosa*, having a wavy-walled *epicarp*, thick-walled *hypoderm*, *outer mesocarp* of stone cells with the characteristic cavities and large spherical cells, *middle mesocarp* with starch, etc.

SPERMODERM.—The layers are similar to those already described.

C. PEPO VAR. ORANGINA SER.

The fruit of this variety differs from that of the type only in macroscopic appearance, having the size, shape, and color of the orange. Rigidity is given the thin rind by the *outer mesocarp* of stone cells.

The small seeds are histologically like those of the preceding variety.

CUCURBITA MAXIMA DUCH.

This species (winter squash) is a native of southern Asia and, like *C. Pepo*, has many varieties differing in size and shape.

The fruit, the largest of the family, varies from 15 to 90^{cm} in length. It is rounded ovate, with warts and occasional longitudinal grooves, and is of a yellow, orange, or green color. In the so-called "turban" variety, the top of the fruit projects beyond an encircling line, or constriction, which marks the margin of the adherent receptacle. The hollow rind with central cavity is filled with bundles and seeds.

The white seeds are 1.5–2.5^{cm} long, smooth, and flattened, with a border.

Both fruit and seed closely resemble in structure *C. Pepo* and its varieties.

PERICARP.—The thin *epicarp*, small-celled *hypoderm*, sclerenchymatized *outer*, thin-walled *middle*, and *inner mesocarp* are like those of *C. Pepo* var. *verrucosa* (*fig.* 7).

SPERMODERM.—The chief difference between this coat and that of the species already described is in the middle spongy parenchyma, which in this seed is five to six cells thick.

Cucumis sativus L.

Cucumis sativus L. (cucumber) occurs native in the East Indies, and from this species have been derived many varieties which have long been cultivated in gardens.

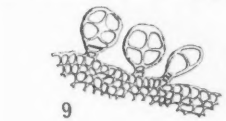
The fruit varies in size, but is always elongated or oval, and rounded triangular in cross-section. It is fleshy and solid, without a central cavity, and of a yellow-white color with white fruit-flesh. Numer us warts cover the surface, each capped with a short blunt spine which readily becomes detached during growth or on handling.

Fig. 8.—*Cucumis sativus* L. Seed. ×1.

Numerous white seeds (*fig. 8*), borne within the three locules, are 1–1.5^{cm} in length, flattened, seldom over 2^{mm} thick, and are not, like those of Cucurbita, provided with a border.

Pericarp (*figs. 9, 11*).—This consists only of the solid fruit-flesh, the bundles occurring throughout the mesocarp and not in a central cavity.

1. *Epicarp* (*epi*).—The prismatic cells form a palisade layer 75 μ in width, with strongly thickened outer and radial walls, and very thin inner ones. The intense color of the fruit is due, not to the cell contents, but to the yellow walls.



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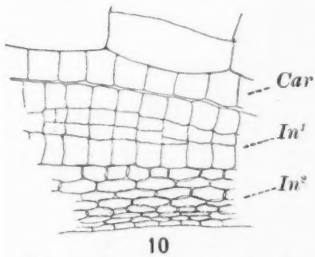

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Fig. 9. *Cucumis sativus* L. Immature epicarp in cross-section, with glandular hairs. ×160.—Fig. 10. *Cucumis sativus* L. Immature seed in cross-section; *Car*, inner carpellary layer; *In*^{1}, outer integument; *In*^{2}, inner integument. ×200.

The warts, which appear before fertilization of the flower, have the same cell structure as the outer layers of the pericarp. Each bears an emergence (*fig. 11*) consisting of large cells with thickened, sparingly pitted walls. They grow rapidly for a short time, but lose their contents soon after their walls begin to thicken.

At its apex the emergence bears a long, jointed (up to ten cells), conical hair, with thickened walls. The cross walls and inner sunken foot, also thickened, are pitted (*t*).

Occasionally a second hair, similar in structure but of smaller size, is developed at the side of the terminal one. The hairs usually disappear in the early stages of growth, but the emergence, unless rubbed off, persists as a brown hyaline spine.

In addition to the hairs of the wart, numerous small capitate hairs, consisting of a four-celled head and stalk of three cells, cover the immature fruit, but disappear early, leaving no scars. Stomata are not present.

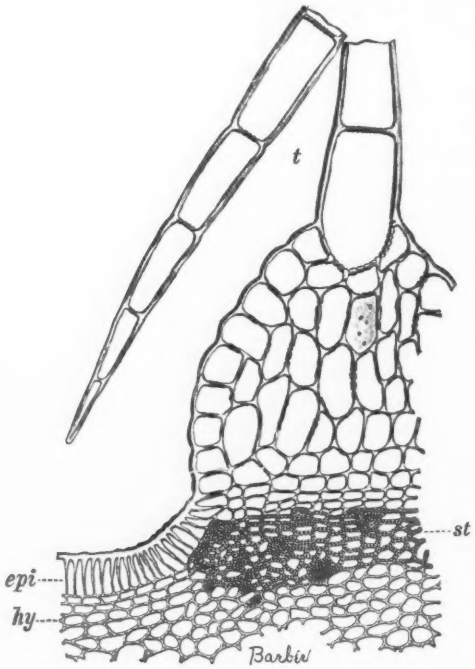


FIG. 11.—*Cucumis sativus* L. Pericarp in cross-section; *epi*, epicarp with emergence bearing *t*, hair; *hy*, hypoderm; *st*, sclerenchymatized cells at base of hair. ×55.

2. *Hypoderm* (*hy*).—A number of layers of small, rounded, loosely arranged cells form the subepidermal tissues. In the young fruit they are filled with chlorophyll grains which entirely disappear at maturity.

At the base of the emergence occurs a group of hypodermal cells which become thickened, sclerenchymatized, and pitted (*st*). This thickening of the cell walls probably serves either to prevent evaporation, or entrance of fungi, or both, after the removal of the emergence. In leguminous seeds there are sclerenchyma cells immediately below the hilum groove which serve this same purpose.

3. *Outer mesocarp.*—MOELLER[22] finds a weakly developed stone

[22] Mikroskopie der Nahrungs- und Genussmittel 473.

cell layer. In the many fruits I have examined, however, the mesocarp does not show any great differentiation. The outer layers consist of rather small thin-walled cells with intercellular spaces.

4. The *middle mesocarp* differs from the outer only in the greater size of the cells.

5. In the *inner mesocarp* the cells become smaller, resembling those in the outer mesocarp. The bundles, isolated sieve tubes, and latex tubes, found throughout the mesocarp, are of the type already described.

6. *Endocarp.*—The elongated, thin-walled cells of this layer remain with the mesocarp and are not attached to the seeds as in Cucurbita.

SPERMODERM (*figs. 10, 12–14*).—Seeds for study should be taken directly from the fruit, as in drying they usually lose their outer walls.

1. *Epidermis* (*fig. 12, ep*).—The prismatic cells are radially elongated to 160 μ on the sides of the seed and 260 μ at the edge. In surface view they are polygonal, transversely elongated, and arranged side by side in rows. The outer and inner walls are thickened, the outer having in addition a cuticle, while the radial walls are very thin, with the characteristic thickenings on only the side walls. Each thickening consists of a single straight rod, broadened at the base and tapering rather abruptly into a blunt almost rounded point just within the cuticle. VON HÖHNEL,[23] in the year 1876, described these rods as consisting of two different layers; FICKEL,[24] the same year, found three; and HARZ,[25] although quoting VON HÖHNEL, pictured three. My own observations corroborate FICKEL'S statement. The three layers can be distinguished by the difference in refractive power and by staining. The inner layer, which gives the color reaction for lignin, shows the strongest refraction; this is surrounded by a thin layer of cellulose (blue with iodin and sulfuric acid) of rather weak refractive power; and this in turn is inclosed in a broader, scarcely visible, second layer of cellulose (also taking the blue stain). Tangential sections show the arrangement of the layers and the elliptical appearance of the cut rods.

[23] *Loc. cit.*, footnote 3, p. 330.

[24] *Loc. cit.*, footnote 2, p. 742.

[25] *Loc. cit.*, footnote 7, p. 773.

2. *Subepidermal layer* (*sub* and *fig. 13*).—On the flattened surface of the seed this tissue consists of one layer of longitudinally elongated cells, arranged end to end in rows, while at the edge they are somewhat shorter and form several layers. They are quite large, ranging from 50–175 μ in length, and have thickened and sclerenchymatized sinuous walls. The most striking feature of the layer, best seen in surface view, is the intercellular spaces which occur in great numbers between the side and end walls. They are very small, several occurring in every turn of the sinuous wall, which is greatly thickened about the space. Between these spaces and also in the outer and inner walls are small pits.

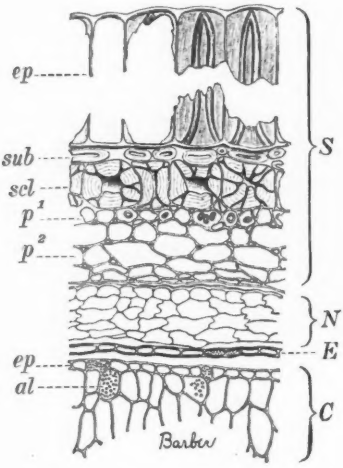


FIG. 12.—*Cucumis sativus* L. Seed in cross-section. *S*, spermoderm consisting of *ep*, epidermis, *sub*, subepidermal layer, *scl*, sclerenchyma, p^1, stellate parenchyma, p^2, spongy parenchyma; *N*, perisperm; *E*, endosperm; *C*, cotyledon consists of *ep*, epidermis and mesophyll with *al*, aleurone grains. ×160.

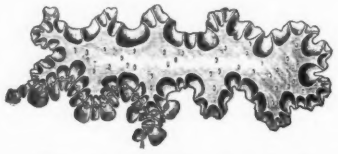


FIG. 13.—*Cucumis sativus* L. Isolated subepidermal cell of spermoderm in surface view. ×300.

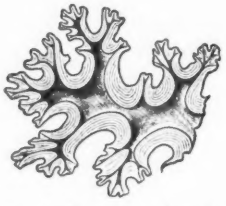


FIG. 14.—*Cucumis sativus* L. One-half of isolated cell of sclerenchyma layer in surface view. ×300.

3. The *sclerenchyma* (*scl* and *fig. 14*) consists of one layer (more toward the edge) of longitudinally elongated (220 μ) cells with narrow cell cavities and very thick lignified walls. Heating with potash brings to view the middle lamella and striations of the wall, but

only after maceration can the overlapping branches of the ramifications be seen. Pits are numerous.

4. *Parenchyma.*—The outer layer (p^1) is one cell thick at the side, increasing in number toward the edge, and consists of small cells more or less stellate in form. This layer is followed by two or three cell layers of thin-walled parenchyma (p^2), which are usually ruptured in dry seeds.

5. The *inner epidermis* consists of small, elongated parenchyma cells.

PERISPERM (*N*).—A number of layers of collapsed, thin-walled cells form this layer. The longitudinally elongated epidermal cells have a cuticle.

ENDOSPERM (*E*).—The cells of this layer are polygonal, 22 μ in diameter, have thickened walls, and contain small proteid granules.

The EMBRYO (*C*) lacks distinctive features.

CUCUMIS MELO L.

All the varieties of musk melon are derived from a single species indigenous to Africa and Asia. HARZ divides the species into nine groups, each with one to ten subspecies.

The fruit varies somewhat in size and shape, but is usually spherical, oval, or occasionally elongated, and has eight to ten longitudinal grooves, differing in depth in different specimens, to which is due the characteristic "melon shape." The surface is green, yellow, or red, with a gray network of corklike tissue.

A rind 2.5 to 5^{cm} thick, with yellow to reddish fruit-flesh, incloses a central cavity containing fibers, seeds, and a considerable amount of watery fluid.

The seeds are like those of *C. sativus*, except that their color is yellow.

PERICARP (*figs. 15–17*).—This consists of the hard rind, and the soft, sweet watery fruit-flesh with bundles.

1. *Epicarp* (*epi*).—The cells of this layer vary in size, shape, and thickness of walls. On the ribs there is a palisade layer of greatly thickened, polygonal cells with a cuticle. In the grooves the cells increase in size, the walls become thinner, and pits make their appearance. In cross-section the cell cavity appears flask-shaped, the

neck running out to a point. *Fig. 15* shows the radiating cell cavity in tangential section.

According to MOELLER,[22] cork cells occur here and there below the epicarp. This I find to be true of the young fruit, but at maturity they break through the epicarp, forming the corky ridges or netted thickenings previously mentioned. The cells are small, thin-walled, and radially arranged, forming a dense mass of cork tissue, which, together with the ruptured epicarp, closely resembles lenticels, but no complementary cells are formed. This likeness is very marked in cross-section (*fig. 16*).

Stomata (*fig. 17, sto*), with guard cells of the usual type, are present in the grooves and, less frequently, in the depressions between the corky ridges. The walls of the accompanying cells have few or no pits and are irregularly thickened. In some instances the whole wall is thickened, while in others large protuberances are sent out into the cavity.

FIG. 15.—*Cucumis Melo* L. Epicarp in tangential section. ×160.

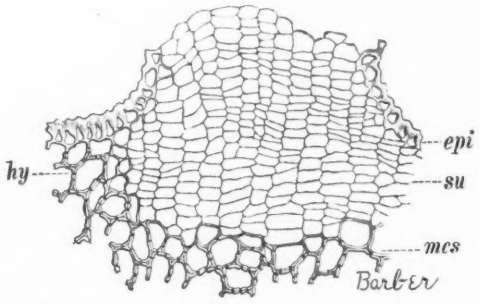


FIG. 16.—*Cucumis Melo* L. Rib of pericarp in cross-section; *epi*, epicarp; *su*, cork; *hy*, hypoderm; and *mes*, mesocarp. ×50.

In the depressions and grooves are jointed (three or more cells), conical hairs up to 375 μ in length (*l*). The diameter at the base is the same as that of the neighboring cells, but gradually diminishes to the apex. The thickened walls have additional minute local thickenings or warts, visible only by the most careful focusing. About the hair scars the cells are distinguished by the smaller cavities and thicker walls.

The immature fruit bears small capitate hairs like those of *C. sativus*.

2. *Hypoderm* (*hy*).—The cells of a number of layers beneath the epicarp are thickened and pitted. Below the thick-walled epidermal cells they are of medium size with intercellular spaces; under the thinner epidermis of the grooves, through which they are visible, they are larger and thinner-walled with very large pits. Chlorophyll is present in greater or less amount even though the fruit appears yellow.

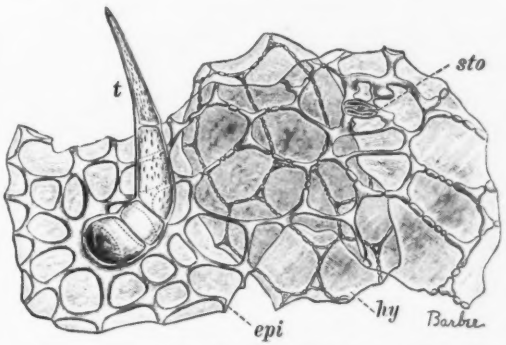


FIG. 17.—*Cucumis Melo* L. Pericarp in surface view; *epi*, epicarp with *t*, hair, *sto*, stoma; *hy*, hypoderm. ×160.

3, 4, 5. The *outer*, *middle*, and *inner mesocarp* of this species consist of cells similar to those of the corresponding layers of *C. sativus*. The placentae, however, instead of persisting intact, are almost if not quite broken down.

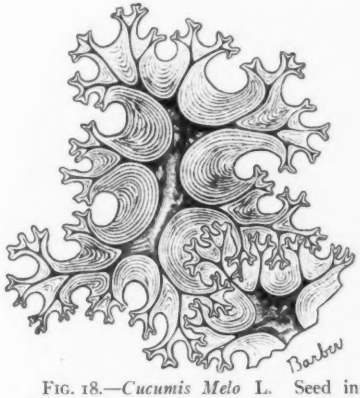


FIG. 18.—*Cucumis Melo* L. Seed in cross-section; *S*, spermoderm consisting of *ep*, epidermis, *sub*, subepidermal layer, *scl*, sclerenchyma, p^1, sclerenchymatized spongy parenchyma, p^2, spongy parenchyma; *N*, perisperm; *E*, endosperm; *C*, cotyledon with *ep*, epidermis, and mesophyll containing *al*, aleurone grains. ×160.

6. *Endocarp*.—As in *C. sativus*, the cells are thin-walled and longitudinally elongated.

SPERMODERM (*fig. 18*).—1. *Epidermis* (*ep*). Seen in surface view the cells are polygonal and in cross-section they reach a length of 200 μ. The outer wall is thickened and the thin radial walls have the characteristic thickenings. HARZ[26] figures this layer with rods

[26] *Loc. cit.*, footnote 7, p. 777.

having small side branches at right angles, and MOELLER[22] describes them as simple rods without branches. Like the latter author, I find single straight rods, one on each radial wall, which stain yellow with iodin and sulfuric acid, thus showing them to contain lignin.

2. The *subepidermal layer* (*sub*) is the most characteristic layer of this seed. Whereas in *C. sativus* it consists of but one cell layer, in this species it has five or six layers of cells longitudinally elongated (except at the edges) and arranged end to end in rows. Both species have sinuous walls and characteristic circular intercellular spaces visible in cross- as well as in longitudinal section. The cells of the outer layer are small, increasing inward in size and thickness of wall with every layer, until the inner one is distinguished from the sclerenchyma only by the somewhat more irregular arrangement and the slightly smaller size of the cells.

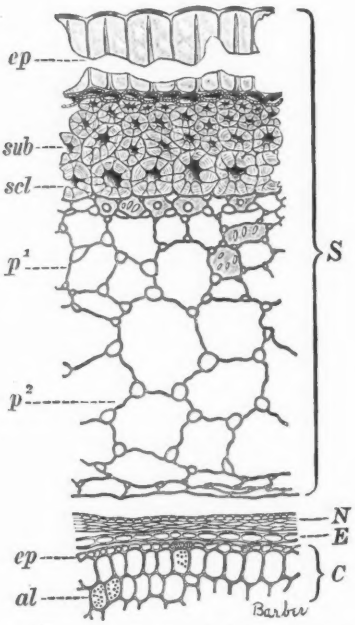


FIG. 19.—*Cucumis Melo* L. Isolated sclerenchyma cell of spermoderm. ×300.

3. *Sclerenchyma* (*scl* and *fig. 19*).—This single cell layer differs from that of *C. sativus* only in the irregular contour of the outer surface, where the layer conforms to the shape of the inner surface of the preceding layer.

4. *Parenchyma* (p^1 and p^2).—Beneath the sclerenchyma are one, sometimes two, layers of small cells, which are thin-walled, sclerenchymatized, and frequently pitted. This tissue gradually changes from without inward to larger-celled parenchyma with larger intercellular spaces.

5. *Inner epidermis.*—A layer of small parenchyma cells makes up this layer.

PERISPERM (*fig. 18, N*), ENDOSPERM (*fig. 18, E*), and EMBRYO (*fig. 18, C*) have the same structure as the corresponding parts in *C. sativus*.

CUCUMIS ERINACEUS L.

The seed of *Cucumis erinaceus* L. (*fig. 20*) is 6–8^{mm} long, 2–3^{mm} broad, and 1–1.5^{mm} thick, flattened, pointed, smooth, and yellow.

FIG. 20.—*Cucumis erinaceus* L. Seed. ×1.

SPERMODERM (*fig. 21*).—This is quite similar to that of *C. Melo*.

1. *Epidermis* (*ep*).—The prismatic cells are radially elongated to 70 μ, increasing in length but slightly if at all over the edge. Each radial wall has one rod broadened at the base and bluntly pointed at the outer end.

2. A *subepidermal layer* (*sub*), about six cells thick, consists of small, tangentially elongated cells, increasing in size over the edge of the seed. They are thick-walled, pitted, striated, and increase in size from without inward. Occasional small intercellular spaces are seen, especially at the edge.

3. *Sclerenchyma* (*scl*).—This single-celled layer, 40 μ in width, differs from the subepidermal layer principally in the greater size of the cells, which are longitudinally elongated and have very thick sinuous walls containing pits.

4. *Parenchyma* (*p*).—The outer layer is made up of very small cells with thin walls and small pits seen only with very high magnification. In the middle layers the cells are somewhat larger, also thin-walled, with intercellular spaces at the angles of the cells.

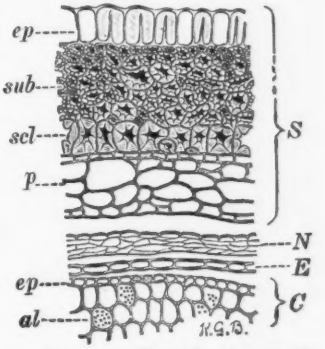


FIG. 21.—*Cucumis erinaceus* L. Seed in cross-section; *S*, spermoderm consisting of *ep*, ribbed palisade epidermis, *sub*, subepidermal layer, *scl*, sclerenchyma layer, *p*, parenchyma; *N*, perisperm; *E*, endosperm; *C*, cotyledon, consisting of *ep*, epidermis, and mesophyll with *al*, aleurone grains. ×160.

5. The *inner epidermis* consists of one layer of very small parenchyma cells.

PERISPERM (*fig. 21, N*), ENDOSPERM (*fig. 21, E*), and EMBRYO (*fig. 21, C*) present no new features.

CITRULLUS VULGARIS SCHRAD.

Citrullus vulgaris Schrad. (watermelon), now extensively cultivated in the tropics and warmer regions of the temperate zone, is a native of South Africa. ENGLER and PRANTL emphasize the fact that on its native soil the fruit forms a considerable part of the food of both the natives and the larger animals. This view is substantiated by LIVINGSTONE in his *Travels in Central Africa*.

The fruit is spherical, or more often ellipsoidal, of a dark green color, frequently mottled with white in ragged, longitudinal stripes several centimeters in width. The rind is firm but not hard, green at the outer surface, white further inward, changing gradually to the glistening pink, red, or yellow inner fruit-flesh, which contains 91–95 per cent. of water.

FIG. 22.—*Citrullus vulgaris* Schrad. Seed. ×1.

In the inner colored fruit-flesh are imbedded the numerous white, brown, or black mottled seeds (*fig. 22*). They are flat, without a border, lustrous, and smooth except when mottled, in which case they are slightly rough.

PERICARP (*figs. 23, 24*).—The great bulk of the fruit is the solid fruit-flesh, and it is this sweet, watery portion that is usually eaten and not the rind as in Cucurbita. The placentae are beautifully outlined, the bundles being of a somewhat lighter color than the flesh. When very ripe the flesh may separate along these lines, but no true cavity is formed. The individual cells of the inner flesh are visible to the naked eye.

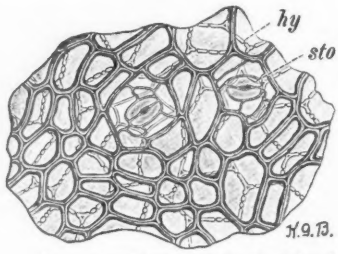


FIG. 23.—*Citrullus vulgaris* Schrad. Pericarp in surface view. Epicarp with *sto*, stoma; *hy*, hypoderm. ×160.

1. *Epicarp* (*epi*).—Instead of the true palisade cells there is a

layer, 33 μ in thickness, of cells often broader than high. The outer wall is very thick, the thickening running down on the radial walls. In surface view the middle lamella is visible and the hypoderm is quite evident through the thick-walled but transparent epicarp.

The ovary and very young fruit bear jointed hairs, which often reach a length of 32^{mm} but are only 84 μ broad. They are borne on stalks of several joints, the foot becoming no larger than the surrounding epidermal cells in which it is imbedded. All the walls are only slightly thickened. These hairs disappear soon after fertilization, leaving scars which are evident only on the immature fruit.

Stomata (*sto*) are very numerous, occurring singly or in groups. They have rather large guard cells and thin-walled accompanying cells.

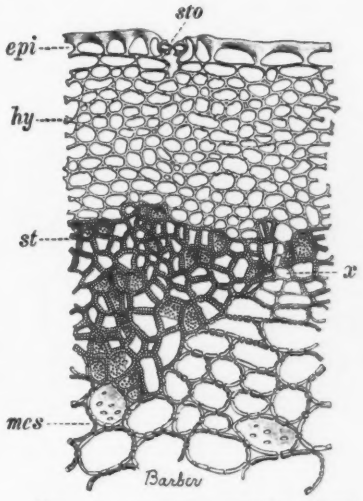


FIG. 24.—*Citrullus vulgaris* Schrad. Pericarp in cross-section; *epi*, epicarp with *sto*, stoma; *hy*, hypoderm; *st*, outer mesocarp (stone-cell layer); *x*, parenchyma between groups of stone cells; *mes*, middle mesocarp. ×160.

2. *Hypoderm* (*hy*).—A layer, many cells thick, containing chlorophyll, forms the green tissue of the rind. The outer layer consists of short cells, resembling those of the epicarp in size and shape; the following layers are made up of cells smaller in size and isodiametric. Numerous pits are present, the walls appearing distinctly beaded in surface view. Small intercellular spaces occur throughout the tissue.

3. *Outer mesocarp* (*st*).—In the very young fruit the cells are small and isodiametric, but after a few weeks single cells or groups of cells thicken their walls and become pierced with pits. These groups are distributed about the fruit just within the hypoderm. As growth of the fruit continues, these cells increase in number, the groups

approaching each other until there is eventually, in the mature fruit, a distinct zone of stone cells surrounding the inner tissues. This stone-cell layer is not quite continuous, the groups being separated in many places by a few cells which retain their thin cellulose walls and afford easy communication between the hypoderm and middle mesocarp (*x*). The inner contour of the layer is very irregular.

4. *Middle mesocarp* (*mes*).—The cells are thickened, pitted, and gradually increase in size from the small outer layers inward.

5. *Inner mesocarp.*—This layer is the great central mass of pink (or yellow) tissue. The cells are of enormous size, often 1.25^{mm} in diameter, and, as previously stated, they can be easily distinguished with the naked eye. The walls are thin and are separated at the angles by intercellular spaces. A sweet, watery liquid fills the cavity.

Bundles, sieve tubes, and latex tubes are found scattered throughout the mesocarp.

6. The *endocarp* consists of one layer of small, very thin-walled, elongated cells as in *C. sativus*.

SPERMODERM (*fig. 25*).—This coat, consisting of the usual number of layers, is thin but very firm.

1. *Epidermis* (*ep*).—Prismatic cells form a palisade layer covered with a thick cuticle, which occasionally reaches a thickness of $35\,\mu$. The outer and inner walls have wavy contours, that of the inner wall being much more pronounced. Each radial wall, which is thicker than in the species previously described, has one thickening in the form of a straight rod pointed at the outer end. Occasionally it branches once dichotomously, the two branches running straight out to the cuticle. These rods are sclerenchymatized, responding to the test with iodin and sulfuric acid. In the colored seeds the brown or mottled appearance is due to the colored contents of the epidermal cells.

2. The *subepidermal layer* (*sub*) consists of a number of layers of sclerenchymatized cells, increasing in number over the edges. The outer cells are small and isodiametric; those of the middle layers, large and radially elongated; while the inner cells are noticeably small. The cell walls increase in thickness from without inward, those of the inner layer having scarcely any cell cavities. All of the walls are sinuous and deeply pitted.

3. *Sclerenchyma* (*scl*).—This layer differs somewhat from the corresponding layer of the other cucurbitaceous seeds. Instead of conspicuously elongated cells arranged end to end in rows, they are but slightly if at all elongated and very irregularly distributed, showing only the faintest indications of an end-to-end arrangement. In other respects, that is as regards thickness and sinuousity of the pitted walls, they are similar.

4. *Parenchyma.*—One layer of small and somewhat spongy cells forms the outer tissue (p^1). They are thin-walled, pitted, and sclerenchymatized. Below are several other layers of more or less spongy parenchyma, the cells decreasing in size toward the inner epidermis (p^2).

5. *Inner epidermis.*—This layer consists of small, thin-walled cells.

PERISPERM (*fig. 25, N*).—An epidermis of longitudinally elongated cells with a cuticle covers a number of layers of thin-walled parenchyma.

ENDOSPERM (*fig. 25, E*).—This is the only species studied in which this layer is more than one cell thick. In *Echinocystis lobata* there are occasional broken-down cells below the thick-walled protein layer, but in the present species the cell

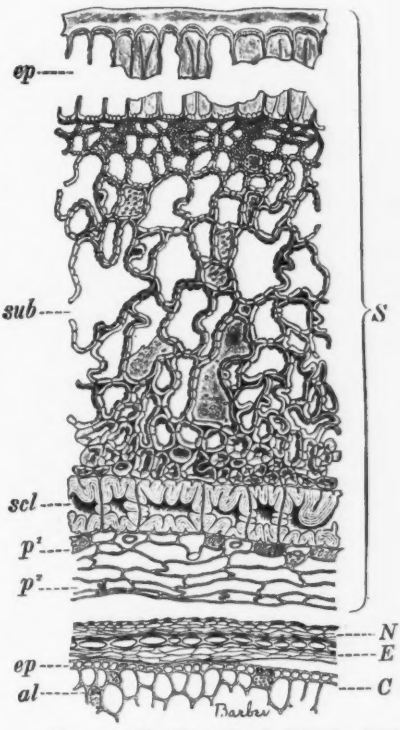


FIG. 25.—*Citrullus vulgaris* Schrad. Seed in cross-section; *S*, spermoderm consisting of *ep*, epidermis, *sub*, subepidermal layer, *scl*, sclerenchyma, p^1, sclerenchymatized parenchyma, p^2, inner parenchyma; *N*, perisperm; *E*, endosperm; C, cotyledon, with *ep*, epidermis, and mesophyll, containing *al*, aleurone grains. ×160.

layers are numerous, forming a tissue as thick as the perisperm. The outer polygonal cells are of the kind described for other species, and the inner layers consist of extremely thin-walled parenchyma, distinguishable only after treatment with Javelle water.

The EMBRYO (*fig. 25, C*) corresponds to that of the general description.

SICYOS ANGULATUS L.

Sicyos angulatus L. is a native of northeastern United States, occurring as a weed in damp places, and is also occasionally cultivated for arbors.

The fruits, each consisting of a small ovate pericarp (up to 2^{cm} in length), filled with a single seed, are borne in capitate clusters on a

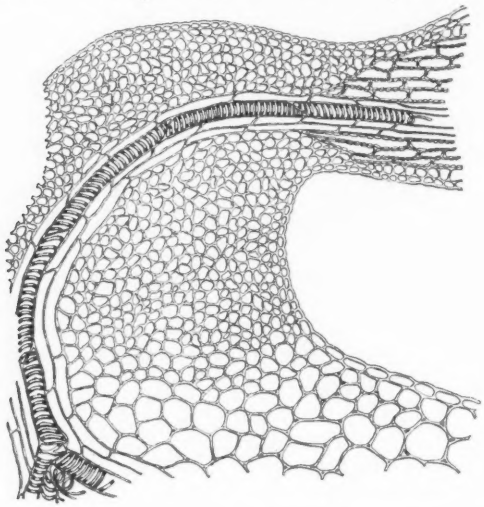


FIG. 26.—*Sicyos angulatus* L. Base of prickle in cross-section, showing characteristic small cells. ×160.

long peduncle. They are dry and covered with deciduous barbed prickles, 8–10^{mm} long, which give them a burrlike appearance.

The brown seeds are 12^{mm} in length and 10^{mm} broad, flattened, ovate, smooth, and lustrous.

PERICARP (*figs. 26–29*).—This coat forms only a very thin covering for the seeds and does not make up the bulk of the fruit, as in the

other species described. The surface is roughened and covered with spines and hairs, of which, as described below, there are four forms.

1. *Epicarp.*—This layer is composed of small flattened cells 13 μ high, with slightly thickened walls. In surface view they are polygonal and 20 μ in diameter (*fig. 29*).

Very striking are the prickles (emergences), each being a long (8–10^{mm}) outgrowth borne on a swelling of the pericarp (*fig. 26*). They have a constricted base, the epidermis of which consists of thin-walled cells. Above this base the epidermal cells elongate and become thickened. Over all the surface of the prickles are borne slightly curved, single-celled, conical hairs (often 135 μ in length), with extremely thick walls (*fig. 27*). They are very stiff and turn sharply backward. Doubtless they play an important part in the dispersal of the seeds, acting as barbs to fasten securely the prickles, and thereby the fruit, to passing animals. Similar pointed but not deflexed hairs occur on the epicarp, either singly or in pairs.

At the end of the prickle there is a thin-walled capitate hair, consisting of a stalk of several short cells and a single-celled glandular head (*fig. 27*).

Among the prickles there are also large glandular hairs, reaching a length twice that of the emergence (*figs. 28, 29, l^1*). The foot consists of one or two enlarged epidermal cells and is surrounded by cells but slightly smaller. From the foot the cells are elongated and thin-walled, the hair tapering gradually and ending with short glandular cells. The prickles become entangled in the hairs and do not fall off, even though detached from the pericarp.

Another form of hair (*fig. 29, l^2*) on the pericarp is thin-walled, unicellular or several-jointed, reaching a maximum length of 540 μ. The end cell is conical and not glandular as in the preceding hair.

Numerous stomata occur among these hairs.

2. *Hypoderm.*—One or more layers of very small isodiametric cells form an inconspicuous layer just within the epicarp. The hypodermal cells of the constricted base of the prickle are also very minute and thin-walled. These together with the thin-walled epidermis permit the prickle to be readily detached at maturity. In the prickle the cells are elongated and sclerenchymatized, with numerous pits (*fig. 26*).

3. *Outer mesocarp.*—Several rows of small rounded cells with intercellular spaces make up this tissue. In the vicinity of the prickles and hairs they are sclerenchymatized and tangentially elongated.

4. The *middle mesocarp* consists of several layers of large-celled, loosely arranged parenchyma with intercellular spaces.

5. *Inner mesocarp.*—The cells of this coat, although somewhat smaller than those of the middle mesocarp, form several layers of similar tissue.

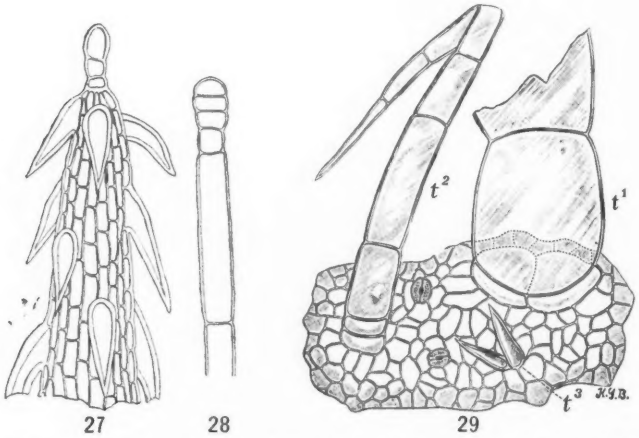


FIG. 27. *Sicyos angulatus* L. Apex of spine. ×160.—FIG. 28. *Sicyos angulatus* L. Apex of long jointed hair. ×160.—FIG. 29. *Sicyos angulatus* L. Epicarp in surface view; t^1, base of glandular hair; t^2, short pointed conical hair; t^3, unicellular conical hair. ×160.

The bundles and latex tubes, few in number, are scattered through the mesocarp.

6. *Endocarp.*—As in *Cucurbita Pepo*, the single layer of longitudinally elongated, thin-walled cells remains on the seed.

SPERMODERM (*fig. 30*).—1. *Epidermis* (*ep*). Prismatic cells form a palisade layer only 50 μ in width. In cross-section no thickenings are apparent on the radial walls, but in surface view, what appeared in the cross-section to be walls thickened at the angles are rods running, one on each wall, from the inner to the outer wall which they seem

to join. No cuticle is present; the thickening, however, is continued on the inner wall.

2. *Subepidermal layer* (*sub*).—Small thin-walled cells, 13 μ in diameter, with intercellular spaces, make up one layer. Additional cells of the same type are present below the radial walls of the epidermis, making the tissue two cells thick in those places.

3. *Sclerenchyma* (*scl*).—As in Echinocystis, there is one layer of radially elongated cells forming a palisade layer, 230 μ in width, which is best seen in cross-section. The cell cavities are narrow, constricted about 70 μ from the outer wall, from which constriction branches radiate toward the outer wall. This is repeated at the other end, the constriction being slightly nearer the inner wall. In surface view the cells are sinuous and indefinitely arranged.

4. *Parenchyma*.—The outer cells are small and thin-walled (p^1) and the several middle layers consist of large stellate cells and intercellular spaces (p^2). All of these layers are sclerenchymatized. About ten layers of spongy parenchyma, the cells decreasing in size inward, form the inner tissues (p^3). These cells contain chlorophyll, which gives the tissue a distinct green color.

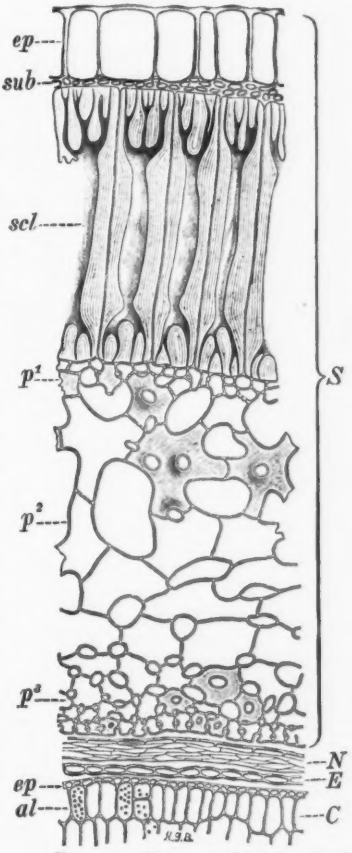


FIG. 30.—*Sicyos angulatus* L. Seed in cross-section; *S*, spermoderm consisting of *ep*, epidermis, *sub*, subepidermal layer, *scl*, sclerenchyma, p^1, small-celled outer parenchyma, p^2, large-celled spongy parenchyma, p^3, small-celled spongy parenchyma; *N*, perisperm; *E*, endosperm. *C*, cotyledon with *ep*, epidermis, and mesophyll containing *al*, aleurone grains. ×160.

5. The *inner epidermis* with small, thin-walled cells resembles that of *Cucurbita Pepo.*

PERISPERM (*fig. 30, N*).—Five or six layers of parenchyma, with outer epidermis and cuticle, have the same structure as the corresponding layer of other species. The most characteritsic feature is the transversely elongated epidermal cells.

ENDOSPERM (*fig. 30, E*).—This consists of one layer of thick-walled cells containing protein granules.

EMBRYO (*fig. 30, C*).—No characteristic features are evident.

ECHINOCYSTIS LOBATA TORR. & GR.

This plant, *Echinocystis lobata* Torr. & Gr. (*Sicyos lobatus* Michx., *Momordica echinata* Muhl.), is one of the two Cucurbitaceae indigenous to New England. It has no value as a food, but is quite extensively cultivated for arbors.

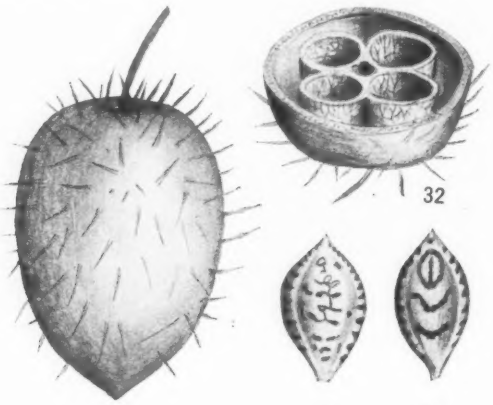


FIG. 31. *Echinocystis lobata* Torr. & Gr. Fruit. ×1.—FIG. 32. *Echinocystis lobata* Torr. & Gr. Fruit in cross-section. ×1.—FIG. 33. *Echinocystis lobata* Torr. & Gr. Seed. ×1.—FIG. 34.—*Echinocystis lobata* Torr. & Gr. Seed. ×1.

The oval fruit (*fig. 31*) is 5^{cm} long, light green in color, and covered with soft spines 12^{mm} in length. At maturity it bursts irregularly at the top, showing the fruit-flesh separated into an outer and inner tissue consisting of a fibrous network. This inner part forms two large oblong cells, each divided at the base into two one-seeded

locules, as shown in *fig. 32*. Soon after dehiscence the pod dries up.

The flattened ovate seeds are 20^{mm} in length, 8^{mm} broad, and 4^{mm} thick. The color is gray brown with beautiful brown markings (*figs. 33, 34*) varying greatly on different specimens. On the flattened surface of some seeds these markings are in the form of circles, on

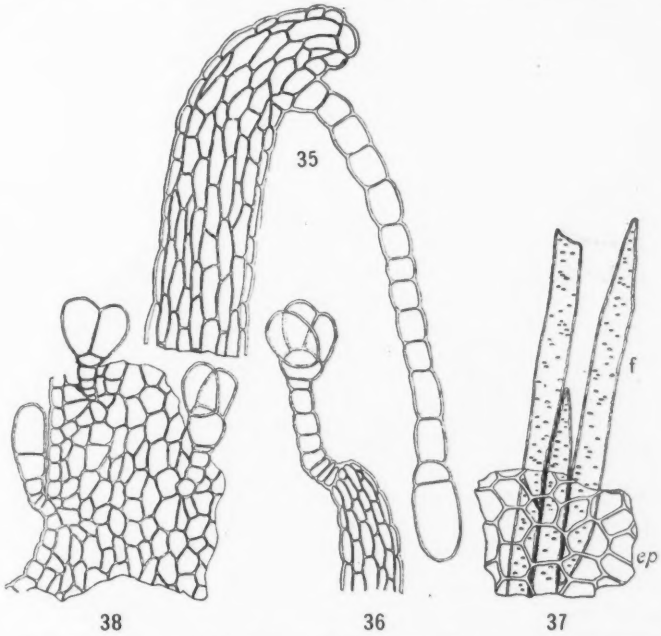


FIG. 35. *Echinocystis lobata* Torr. & Gr. Apex of emergence from immature pericarp. ×160.—FIG. 36. *Echinocystis lobata* Torr. & Gr. Apex of emergence from immature pericarp. ×160.—FIG. 37. *Echinocystis lobata* Torr. & Gr. Mature spine in surface view; *ep*, epidermis; *f*, fibers of hypoderm. ×160.—FIG. 38. *Echinocytis lobata* Torr. & Gr. Base of emergence from immature pericarp. ×160.

others as various shaped spots, but about the edge they generally form a border of elongated diagonally arranged blotches. The embryo differs from the typical embryo only in the greater thickness of the cotyledons.

PERICARP (*figs. 35–39*).—The outer part, or prickly rind, consists of

the epicarp and outer mesocarp, the inner of the hard, stiff bundles with only vestiges of ground tissue.

1. *Epicarp* (*figs. 37, 39*).—The cells of this layer are slightly thickened, in surface view appearing polygonal and distinctly beaded. On the spines the epidermal cells are elongated and have thick walls.

The tip of each spine (*figs. 35, 36*) curves decidedly, bearing at the very extremity, or more frequently just below it, a long, jointed, capitate hair. There is great variation among these hairs. They point downward, upward, or in an intermediate direction; the joints may be few or many, the length of the hair varying accordingly. Each cell is about as long as broad, with moderately thickened outer and slightly thinner cross walls. The head consists of one cell (*fig. 35*), two (*fig. 38*), arranged side by side, or three (*fig. 36*), arranged about a common axis. They have free rounded ends and are elongated, with longitudinal diameter twice that of the transverse.

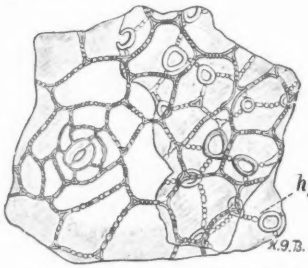


FIG. 39.—*Echinocystis lobata* Torr. & Gr. Pericarp in surface view; epicarp with *hy*, hypoderm. ×160.

Similar hairs, but much shorter, with one- to three-celled stalks, are present on the sides of the spine (*fig. 38*). All of the hairs frequently disappear before the fruit reaches maturity.

Interspersed among the spines are the stomata with small pitted accompanying cells.

2. *Hypoderm* (*fig. 39, hy*).—Several layers of pitted cells make up this layer. They are polygonal, thick-walled, and have circular intercellular spaces at the angles, about which the walls are very thick. In the spines the walls are also thickened and pitted, and in addition very much elongated longitudinally. The hypoderm shows through the transparent epicarp, the circular intercellular spaces, with strongly thickened surrounding walls, being especially characteristic.

3. *Outer mesocarp.*—Several layers of isodiametric parenchyma cells form the tissue below the hypoderm. The cells are small and thin-walled.

4. The *middle mesocarp* cells are large, thin-walled, and mostly broken down in the mature fruit, thus forming the cavity between the outer rind and inner fibrous tissue.

5. *Inner mesocarp.*—Groups of small parenchyma cells, with structure similar to that of the middle mesocarp, are found between the bundles.

The numerous large bundles make up the bulk of the mature mesocarp, the anastomosing branches forming the fibrous network. Into each of the spines passes a small bundle which connects with this netted system.

Latex tubes are present in the young fruit, but very few or none are found with the dry bundles of the mature pericarp.

6. The *endocarp* (*fig. 41*) persists on the seed as a single layer of very thin-walled cells, longitudinally elongated and arranged side by side in groups.

SPERMODERM (*figs. 40, 42, 43*).—This thick, hard coat is best studied after bleaching with Javelle water.

1. *Epidermis* (*ep*).—The cells differ markedly from those of the seeds previously described in that they vary greatly in height throughout, owing to irregularities, not in the sur-

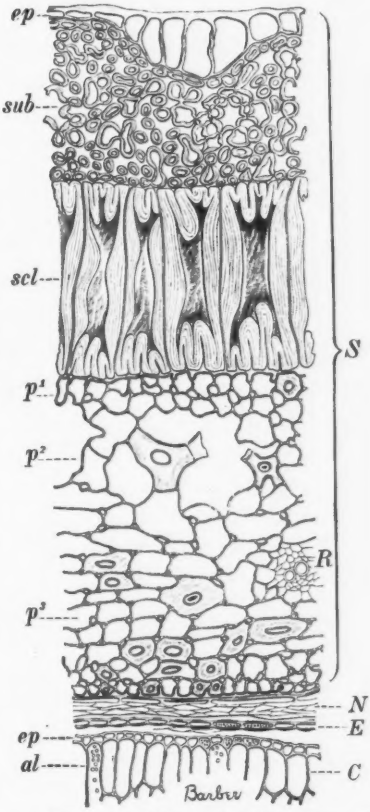


FIG. 40.—*Echinocystis lobata* Torr. & Gr. Seed in cross-section; *S*, spermoderm consisting of *ep*, epidermis, *sub*, subepidermal layer, *scl*, sclerenchyma, p^1, small-celled sclerenchymatized parenchyma, p^2, spongy sclerenchymatized parenchyma with *R*, raphe bundle, p^3, spongy parenchyma; *N*, perisperm; *E*, endosperm; *C*, cotyledon with *ep*, epidermis, and mesophyll containing *al*, aleurone grains. ×160.

face of the seed, but in the subepidermal layer. A cross-section best illustrates this characteristic feature. The cells are much shorter than broad, except where they suddenly elongate, running down into the grooves of the subepidermal layer to form palisade cells about 54 μ in height. In surface view the whole radial wall is thickened, without the thickened rods so characteristic of other seeds.

2. *Subepidermal layer* (*sub*).—This coat, which varies in thickness, as above described, always consists of numerous (ten to fifteen)

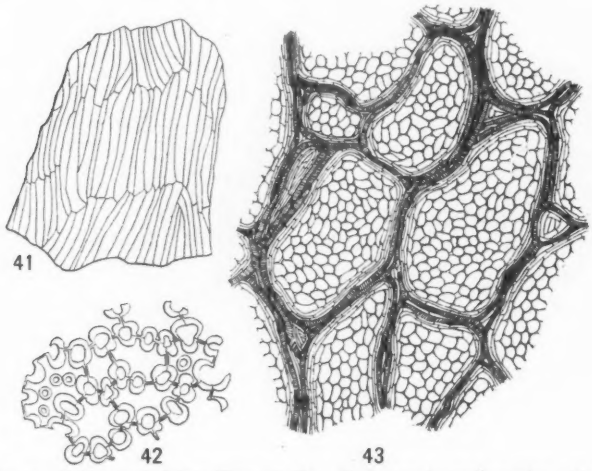


FIG. 41. *Echinocystis lobata* Torr. & Gr. Endocarp in surface view., ×300.—FIG. 42. *Echinocystis lobata* Torr. & Gr. Subepidermal layer in tangential section. ×300.—FIG. 43. *Echinocystis lobata* Torr. & Gr. Parenchyma with raphe in surface view. ×80.

layers of sclerenchymatized cells. They are very loosely arranged, with large circular spaces surrounded by thickened walls. In cross-section the tissue appears only as a confused mass of cells, but in tangential section (*fig. 42*) the contour of the walls is very distinct. The seed owes its color to the dark contents of the outer cell layers.

3. *Sclerenchyma* (*scl*).—In cross-section this single cell layer appears as a palisade tissue, the cells, while only 40 μ broad, being radially elongated to 180 μ. The walls are extremely thick and the

cavities narrow, each sending out branches to the layers above and below. The folds of the sinuous outer and inner walls are also conspicuous in cross-section. In surface view the cells have sinuous walls and are irregularly arranged.

4. *Parenchyma.*—The outer layer (p^1) consists of small, thin-walled, and sclerenchymatized cells without pits. It bears no resemblance to the corresponding layers of Cucurbita. Adjoining this layer are two or three layers of true spongy parenchyma with large cells, thin walls, and large intercellular spaces (p^2). From this tissue the cells decrease in size inward for about fifteen layers (p^3).

The branching and anastomosing *raphe* ramifies through this inner parenchyma. Although each branch contains but few bundle elements, the branches are so numerous that they form a conspicuous tissue, best seen in surface view (*fig. 43*).

5. The *inner epidermis* corresponds in structure to that of *Cucurbita Pepo*, consisting of a layer of small cells with thin walls, the circular contour of the radial walls being very noticeable.

PERISPERM (*fig. 40, N*).—The structure of this tissue is the same as that of the seeds already described, consisting of several layers of thin-walled parenchyma and an outer epidermis with cuticularized outer and radial walls. The epidermal cells are elongated, in many places transversely.

ENDOSPERM (*fig. 40, E*).—One layer of uniformly thickened cells, containing protein granules, forms this coat. In one or two seeds examined there were indications of broken-down parenchyma.

The EMBRYO (*fig. 40, C*) corresponds to the general description, the cotyledons having minute epidermal cells and mesophyll filled with oil and protein granules.

LUFFA CYLINDRICA ROEM.

The smooth, flattened seed (*fig. 44*) is 12^{mm} long, $6–7^{mm}$ broad, and $2–3^{mm}$ thick, of a dark-brown or black color.

SPERMODERM (*figs. 45–47*).—This is thick and consists of the following layers:

1. *Epidermis* (*ep*).—The palisade layer varies from 30–60 μ in thickness, the outer surface having a sinuous contour. On each of the radial walls is a single rod (*fig. 45*) which, instead of ending free

at the outer end, joins the thickened outer wall. The contents are of a dark-brown color.

2. The *subepidermal layer* (*sub*) consists of two quite distinct tissues. Within the epidermis is a layer, one to five cells thick, consisting of small reticulated or pitted cells. In tangential section (*fig. 46*) the zig-zag walls are seen to project into the cavity, with an intercellular space in the angle of each projection.

The second tissue consists of one layer of cells, 20 μ in thickness, polygonal and regularly arranged in cross-section, and slightly elongated tangentially.

3. A *sclerenchyma layer* (*scl*) of cells radially elongated up to 235 μ forms this characteristic layer. The outer and inner walls are sinuous, sending out peculiar branches. The cavity, best seen in cross-sec-

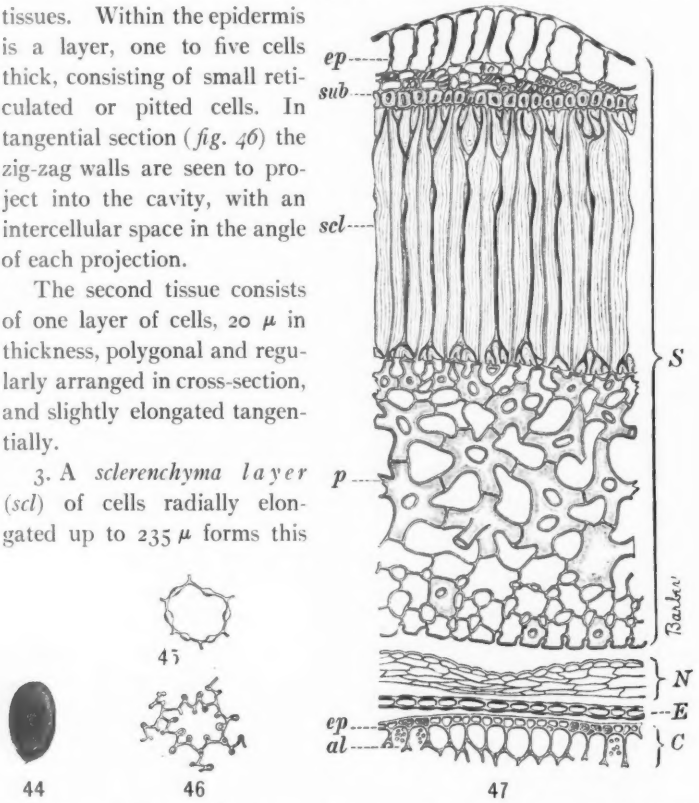


FIG. 44. *Luffa cylindrica* Roem. Seed. ×1.—FIG. 45.—*Luffa cylindrica* Roem. Tangential section of spermoderm, showing rods on radial walls of epidermis. ×160.—FIG. 46. *Luffa cylindrica* Roem. Tangential section of spermoderm, showing radial walls of subepidermal layer. ×300.—FIG. 47. *Luffa cylindrica* Roem. Seed in cross-section; *S*, spermoderm consisting of *ep*, epidermis, *sub*, subepidermal layer, *scl*, palisade sclerehncyma, *p*, parenchyma; *N*, perisperm; *E*, endosperm; *C*, cotyledon with *ep*, epidermis, and mesophyll containing *al*, aleurone grains. ×160.

tion, is extremely narrow, with a globular enlargement just without the center, the two ends branching and running into pits at the outer and inner tangential walls. In tangential section the polygonal cells are 30–45 μ in diameter.

4. *Parenchyma* (*p*).—A number of layers of large stellate cells form the spongy parenchyma. All the walls are thin, the cross walls being pierced with pits. In the outer layers the walls are sclerenchymatized.

5. *Inner epidermis.*—This layer of small parenchyma cells is also somewhat stellate.

The PERISPERM (*fig. 47, N*), ENDOSPERM (*fig. 47, E*), and EMBRYO (*fig. 47, C*) are of the usual type.

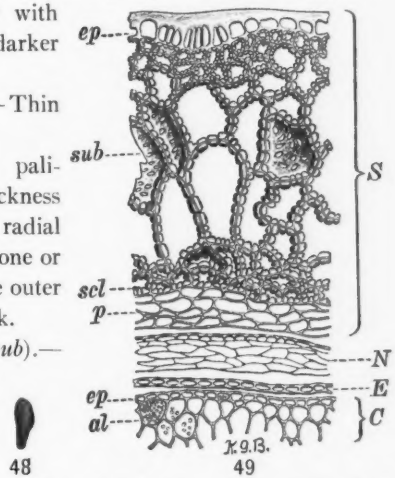
ABOBRA VIRIDIFLORA COGN.

The seed of *Abobra viridiflora* Cogn. (*fig. 48*) is 7–8^{mm} long, very slightly flattened, the enlarged apex being 2–3^{mm} broad and 1.5–2^{mm} thick, of a deep-brown color with longitudinal dashes of a darker brown.

SPERMODERM (*fig. 49*).—Thin but firm.

1. *Epidermis* (*ep*).—The palisade epidermis varies in thickness from 16–45 μ. On the thick radial walls of the larger cells are one or more straight rods joining the outer wall, which is extremely thick.

2. *Subepidermal layer* (*sub*).—This broad layer, six to ten cells thick, consists of very thick-walled, pitted cells irregularly arranged. The outer, and frequently the inner, cells are small, but the middle ones are of enormous size. Few or no intercellular spaces are present.



48 49

FIG. 48. *Abobra viridiflora* Cogn. Seed. ×1.—FIG. 49. *Abobra viridiflora* Cogn. Seed in cross-section; *S*, spermoderm consisting of *ep*, epidermis, *sub*, subepidermal layer, *scl*, sclerenchyma, *p*, parenchyma; *N*, perisperm; *E*, endosperm; *C*, cotyledon with *ep*, epidermis, and mesophyll containing *al*, aleurone grains. ×160.

3. *Sclerenchyma* (*scl*).—Small, thick-walled, pitted, irregularly arranged cells make up this layer, which has no sharp line of demarkation from the preceding layer.

4. The *parenchyma* (*p*) consists of several layers of small thin-walled cells.

5. *Inner epidermis.*—One layer of parenchyma cells makes up this indistinct inner tissue.

The PERISPERM (*fig. 49, N*) of several cell layers, ENDOSPERM (*fig. 49, E*) of one layer of thick-walled cells, and EMBRYO (*fig. 49, C*) are like those described in the introduction.

MELOTHRIA SCABRA COGN.

FIG. 50. — *Melothria scabra* Cogn. Seed. ×1.

The yellow-white seed (*fig. 50*) is 4–5^{mm} long, 2^{mm} broad, and 0.75^{mm} thick, flattened, pointed, and smooth.

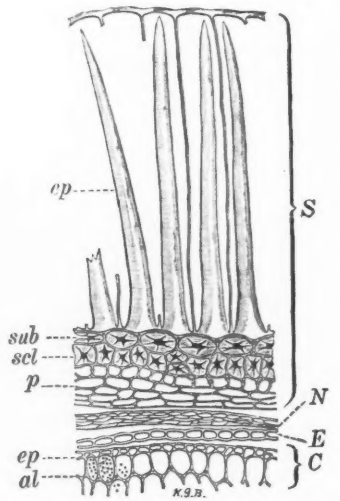


FIG. 51.—*Melothria scabra* Cogn. Seed in cross-section; *S*, spermoderm consisting of *ep*, epidermis, *sub*, subepidermal layer, *scl*, sclerenchyma, *p*, parenchyma; *N*, perisperm; *E*, endosperm; *C*, cotyledon with *ep*, epidermis, and mesophyll containing *al*, aleurone grains. ×160.

SPERMODERM (*fig. 51*).—Consists of five layers, and has a microscopic structure resembling that of *Cucumis sativus*.

1. *Epidermis* (*ep*).—A palisade layer, 270 μ in width, forms the outer layer, which, as in Cucumis, is frequently absent on the dry seeds. The walls are thin except for a single, straight, pointed rod on each radial wall.

2. *Subepidermal layer* (*sub*).—This single layer is composed of thick-walled cells having pits and distinct laminations. At the edge of the seed the layer increases from two to five cells in thickness, the outer ones being elongated radially.

3. *Sclerenchyma* (*scl*).—Small pitted cells, longitudinally elongated, make up the third layer.

4. *Parenchyma* (*p*).—Several layers of thin-walled parenchyma without characteristic features form the inner tissue of the spermoderm. Only with high magnification can the pits in the outer layer be seen.

5. *Inner epidermis.*—As in the other species, this tissue consists of a single layer of thin-walled cells.

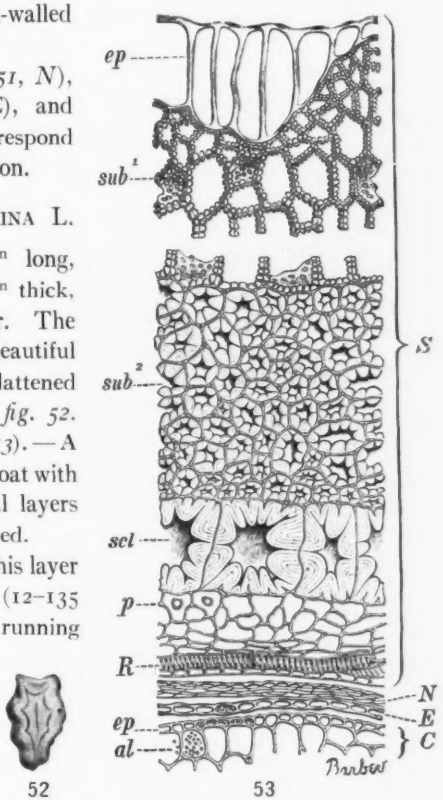
The PERISPERM (*fig. 51, N*), ENDOSPERM (*fig. 51, E*), and EMBRYO (*fig. 51, C*) correspond with the general description.

TRICHOSANTHES COLUBRINA L.

The seeds are 15^{mm} long, 8–9^{mm} broad, and 4–5^{mm} thick, of a gray-brown color. The irregular contour and beautiful dark markings on the flattened surface are illustrated by *fig. 52*.

SPERMODERM (*fig. 53*).—A very hard and thick seed coat with two distinct subepidermal layers is characteristic of this seed.

1. *Epidermis* (*ep*).—This layer is very irregular in width (12–135 μ). The larger cells, running down into grooves of the second layer, bear straight rods on their radial walls. These rods join the thickened outer wall and in cross-section are indistinguishable from the walls at the angles. All of the walls are impregnated with a



52 53

FIG. 52. *Trichosanthes colubrina* L. Seed. ×1.—FIG. 53. *Trichosanthes colubrina* L. Seed in cross-section; *S*, spermoderm consisting of *ep*, epidermis, *sub*¹, outer and *sub*², inner subepidermal layers, *scl*, sclerenchyma, *p*, parenchyma with *R*, raphe; *N*, perisperm; *E*, endosperm; *C*, cotyledon with *ep*, epidermis, and mesophyll containing *al*, aleurone grains. ×160.

brown coloring matter and starch is present in considerable quantity.

2. *Subepidermal layer.*—As previously stated, this layer is divided into two distinct tissues: the outer (*sub*[1]) consists of cell layers increasing in size from the small outer cells inward, with numerous pits in the thickened walls; below this tissue is a second (*sub*[2]), many cells thick, consisting of very thick-walled cells with small branching cavities and small intercellular spaces at the angles. The walls of both tissues are brown.

3. The *sclerenchyma* (*scl*), consisting of large, longitudinally elongated cells of the general type, forms a third sclerenchyma tissue which is impregnated with a brown substance.

4. *Parenchyma* (*p*).—Medium-sized thin-walled cells, the outer layer somewhat stellate, make up this layer. Chlorophyll is present in the inner layers in considerable quantity.

The *raphe* (*R*) branches out over the sides of the seed, the small bundles being found throughout the inner parenchyma.

5. An *inner epidermis* of thin-walled parenchyma cells completes the spermoderm.

The cells of the PERISPERM (*fig. 53, N*), ENDOSPERM (*fig. 53, E*), and EMBRYO (*fig. 53, C*) are not characteristic in this species.

YALE UNIVERSITY

THE ANATOMY OF ISOETES

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 126

ALMA G. STOKEY

(WITH PLATES XIX—XXI)

There is no group of plants among pteridophytes whose anatomy has occasioned so much discussion as the genus Isoetes. The most recent writers, FARMER on *I. lacustris*, R. WILSON SMITH on *I. echinospora*, and SCOTT and HILL on *I. Hystrix*, disagree in many points. In view of the lack of harmony, both of observation and interpretation, it has seemed advisable to make a comparative investigation of the anatomy of several American species.

Historical

The literature on the anatomy of Isoetes began in 1840 with a paper by VON MOHL (**24**). Although he recognized the lycopod affinities of Isoetes, he noted several important points of difference, in the arrangement and structure of the roots, and in the nature of the cambium products. Ever since that day the question of the nature of the cambium activity has afforded a fertile field for discussion, and it is with that subject that this paper is chiefly concerned. VON MOHL regarded the whole of the secondary growth as parenchymatous, and states that, as in other vascular cryptogams, there is no increase in thickness of the wood. The next significant work was that of HOFMEISTER (**16**) in 1857. In discussing the cambium products he says (p. 361): "The effect of the yearly renovation of the cambial layer is not only to increase and renew the cortical tissue, but new spiral cells also become added, although only sparingly, to the wood of old vigorous plants. Individual cells of the cambium, separated by two or three cambium cells from the older principal mass of the wood, often exhibit thickenings of the walls, which by their delicacy and want of color betray their undoubted recent origin." In 1873 appeared RUSSOW'S *Vergleichende Untersuchungen der Leitbündel-Kryptogamen* (**18**), with a discussion of the anatomy of *I. lacustris*, *I. echinospora*, and *I. Hystrix*. This paper has had great influence on subsequent work, and to RUSSOW'S work may be attributed the cur-

rent conceptions of the nature of the cambium products, i. e., that the cambium produces cortex externally to itself, but internally it produces a tissue which he calls the "prismatic layer," and this he regards as being made up of phloem cells, tracheids, and parenchyma. HEGELMAIER (**12**), writing in 1874, is inclined to question RUSSOW's interpretation, but adds that no decisive grounds can be given against the interpretation of the *Dauerzellen* as soft bast. FARMER (**9**) published in 1890 a very full discussion of *I. lacustris*. He seems reluctant to accept RUSSOW's theory of the nature of the cambium products, but does not offer another. After quoting RUSSOW he adds: "Quite apart from the fact that it is produced internally to the cambium and would, from the point of view of its position, be anomalous, its structure is remarkably complex and heterogeneous." In discussing the structure of the "prismatic layer" he says:

> The zone-like arrangement consists in alternations of tubular thin-walled cell-rows of varying thickness, whose cell contents are clear and watery, with others, whose cells are wider in the radial direction, and filled densely with starch. Occupying a middle position in the latter zone is embedded an irregular ring of cells whose walls are thickened like those of the tracheids, but these too, unlike the latter, often contain protoplasm and starch.

In 1900 R. WILSON SMITH (**22**) discussed the morphology of *I. echinospora*, with some incidental work on its anatomy. His observations do not agree with those of FARMER on *I. lacustris*, and he proposes "to drop the term phloem until its justification is established on physiological grounds." In the same year there appeared a very exhaustive paper on *I. Hystrix* by SCOTT and HILL (**19**). The nature of the cambium products was taken up, and RUSSOW's conception was indorsed, in that they regard the secondary tissues internal to the cambium as consisting of secondary tracheids, parenchyma, and phloem. Their statement is as follows:

> The cambium in *I. Hystrix*, arising in the tissues just outside of the xylem cylinder, continues its activity indefinitely, producing parenchyma, phloem, and a variable amount of secondary xylem on its inner side, and secondary cortical parenchyma only, towards the exterior.

Each of the last three writers has based his conclusion on the study of a single species, while RUSSOW, who investigated three forms, was hampered by the fact that he worked on herbarium material. The

desirability of a comparative study of several species embracing a considerable range of habit is obvious.

Material

I am indebted for material of *I. Tuckermani* var. *Harveyi* (A. A. Eaton) Clute (*I. Harveyi* A. A. Eaton) to Dr. LEROY H. HARVEY, who made a collection at Pushaw Pond, Maine, of plants in various stages of development; to Mr. WILHELM SUKSDORF for material of *I. Nuttallii* Engelm. (*I. Suksdorfii* Baker) collected at Bingen, Wash.; and to Dr. H. C. COWLES for material of *I. echinospora* var. *Flettii* which he collected at Spanaway Lake, Wash., in the summer of 1907. The latter material has been kept in cultivation at the greenhouses of the University of Chicago and has afforded abundant material for the study of a close series of stages in the development of the stem. I am also indebted to the late Mr. A. A. EATON of the Ames Botanical Laboratory, North Easton, Mass., for the determination of *I. melanopoda* Gay.

For killing and fixing the stems a medium solution of chrom-acetic acid was used. The material was embedded in paraffin and cut in serial sections 7 to 12 μ thick. Some of the series were transverse and others longitudinal, both parallel and perpendicular to the furrow. A considerable number of stains and combinations of stains were used, of which the most satisfactory were the following: a combination of safranin and anilin blue devised by Dr. LAND; iodin green and Bismarck brown; iodin green and eosin.

The four species studied present a considerable range in habit. *I. Tuckermani* var. *Harveyi* is a submersed form which grows in water 30–150^{cm} deep. The trunk is deeply two-lobed, occasionally three-lobed. The leaves are short, strongly recurved, without stomata, and said by Eaton (**8**) to be relatively the stoutest of any North American species, being 5–6^{cm} in length and 2.5–3^{mm} in diameter. *Isoetes echinospora* var. *Flettii* grows on the gravelly edges of mountain lakes in Washington. In the spring it may be submersed, but during most of the year it is out of the water. The gravel holds water so that the substratum is never very dry. The trunk is two-lobed and the leaves are moderately stout. The largest form studied is *I. melanopoda*. It has a large two-lobed trunk, with

very long, moderately stout leaves. It grows in inundated fields and shallow ponds, where it is emersed during most of the summer. *I. Nuttallii* has a three-lobed trunk and long, very slender leaves. It never grows under water, but near springs or springy places, and on low wet grounds or meadows, where the ground becomes very dry in the latter part of the season.

Investigation

The complicated structure and arrangement of the old stem is more easily understood by a study of the sporelings. The stem of a sporeling is a mass of undifferentiated parenchyma, traversed by leaf traces, which come together to form the short flat stem plate and continue outward and downward into the roots. All observers agree that in the young plants there is no cauline portion in the stem bundle, but whether or not there is a cauline portion in the older stems has long been a disputed point. HOFMEISTER, DE BARY, CAMPBELL, and FARMER look upon the stem bundle as being made up of leaf traces; while HEGELMAIER, BRUCHMANN, and SCOTT and HILL maintain that there is a cauline portion. In the short and compact stem there are no indications of a procambial strand, and as there are never any tracheids present above the last leaf trace, the evidences of a cauline portion are not satisfactory. In following the cross-sections of leaf traces in a series of longitudinal sections up to the place where the traces coalesce, it is easily seen that there is a sufficient amount of tracheary tissue in the leaf traces to account for all the xylem in the stem bundle. SCOTT raised the objection that the tracheids of the stem are unlike those of the leaves, but there is no greater difference between the tracheids of the stem and of the base of the leaf, than between those of the base of the leaf and of the upper part. The difference is chiefly one of length, and this, together with differences in the distribution of the thickening of the walls is correlated with the rate of growth of the part in which the tracheids are found.

In all plants there is a separation into root and stem regions, and this becomes more marked as the plant enlarges. This suggests that the tuberous body is not wholly stem, but a contracted stem and main root. Owing to the compact growth and the consequent displacement of tissues, some of the root bundles in an old plant may be found higher

up in the cortex than the old leaf traces. In fact it is not uncommon, in sections of old stems cut at the very apex of the stem, to find in the cortex a longitudinal section of a root making its way out. Hence, although the stem and root regions are sharply marked off in the central axis, it is impossible to delimit these regions in the cortex. In the young plant shown in *fig. 4*, all the leaf traces and root bundles are functional. In the plants shown in *figs. 19, 20*, all the roots are dead except a few at the bottom, and all the leaf traces except a very few at the top. As the plant increases in size, the old leaf traces are unable to keep up with the growth of the stem and are torn apart, leaving the old stumps attached to the central axis, while the rest of the leaf trace is carried out farther and farther by the growth of the cortex, and in time is sloughed off.

The arrangement of the roots is described in great detail by SCOTT and HILL for *I. Hystrix*, a three-lobed form. The two-lobed trunks show no essential variation from that type, and it is therefore not necessary to give a detailed discussion of the subject. *Fig. 6* illustrates the appearance of the lower part of the stem in cross-section, showing the relative position of the roots of various ages. The roots near the center, which are outlined by dots, are those in meristematic condition; next to them are the mature active roots which are indicated by shaded circles; beyond the mature roots are those which are dead and crushed. The relation of the sets of roots is indicated in *fig. 19* also. The arrangement of the roots in the two-lobed species was first correctly worked out by HOFMEISTER; the youngest sets of roots are those nearest the furrow; and of those in the furrow, the youngest are at the ends.

THE ROOT

The structure of the roots has been described so many times that it is unnecessary to take it up in detail. The most interesting feature is that they are collateral and monarch, without showing any traces of reduction. As the root bundle passes out from the vascular axis it is a round or flattened bundle surrounded by parenchyma. At a short distance from the stem, phloem replaces the parenchyma on the side away from the center of the stem. The phloem is always limited to one side and is small in amount in comparison with the xylem. There is also proportionally much less than in the leaf traces. The

protophloem and protoxylem are usually differentiated about the same time, but the protophloem occasionally precedes the protoxylem. The complete differentiation of the phloem is usually complete before that of the xylem. The differentiation of the xylem in the roots is much slower than in the leaf traces. *Fig. 7* illustrates the structure of a root bundle before it is completely developed and while it is still in the cortex. The eccentric position of the bundle in mature roots is shown in *fig. 8*. While the root bundle is making its way through the cortex the endodermis is poorly differentiated, but in the mature root outside of the stem it is well defined. The pericycle is poorly developed. It is usually entirely absent opposite the phloem, but opposite the xylem there is usually a small amount.

THE LEAF

The leaves of the four species studied present considerable variation, both in general appearance and anatomy.

The leaf of *I. echinospora* var. *Flettii* is moderately stout, and quadrangular in outline (*fig. 9*). In the cortex and lower part of the leaf the bundle is fairly well developed, but above the sporangium it becomes a slender strand. The bundle is collateral throughout, but tends to become concentric in the upper part. The differentiation of the phloem regularly precedes that of the xylem, as was found by KRUCH (**17**) in the species which he studied. The protoxylem in most cases is plainly exarch, but sometimes the differentiation is nearly simultaneous. In this species I found no cases of distinctly mesarch protoxylem. It is common for the metaxylem to develop in three directions from the protoxylem, but I found no cases in which it developed on the fourth side, i. e., on the side toward the phloem, although KRUCH and SCOTT and HILL find that in their species the bundle tends to become mesarch in the region of the sporangium. There is evidently a certain difference in this respect in different species, for in *I. Nuttallii*, which I shall discuss later, mesarch protoxylem is sometimes present. While the protoxylem and metaxylem are both composed of spiral and annular tracheids, or tracheids with irregular spirals, the protoxylem can usually be recognized by the fact that the spirals and rings are looser. The protoxylem cells of the lower part of the leaf are small and are the

first to show signs of crushing, but those in the upper part are large and later form canals by the loss of the thickened portions. In the upper part of the leaf the protoxylem is usually limited to a single large vessel, whose place can be recognized in old leaves by the large canal formed by its disappearance (*fig. 13*); but in the lower part of the leaf, as well as in the leaf trace, the protoxylem cells are smaller, several in number, and less sharply marked off from the metaxylem. *Fig. 10* represents the section of a young leaf near the tip, in which the only indication of the protoxylem is the large central cell, which is not yet thickened, while the phloem is represented by several cells. The phloem consists of very long and slender tubes whose sieve plates are terminal. They come out clearly in sections stained in anilin blue or Bismarck brown. Although several preparations suggest the presence of thin areas on the lateral walls, the evidence is not conclusive. In the portion of the leaf above the ligule there is a very abrupt decrease in the amount of xylem, but not a corresponding decrease in the phloem. The phloem is well developed throughout, but instead of forming a band on one side of the bundle, as in the lower part of the leaf, it forms an arc. The phloem does not disappear from the center of the arc, leaving two lateral groups such as KRUCH has described in *I. Hystrix*, *I. Duriaei*, and *I. velata*, but the amount in the center of the arc is variable. Near the top of the leaf the phloem is sometimes most abundant in the middle of the arc. In *fig. 14* is shown a leaf trace from the cortex at the base of the leaf. This is the type of bundle which is found in the leaf trace as it traverses the outer part of the cortex, and in the leaf itself from its base to the ligule. Just above the ligule, the bundle passes abruptly into the reduced type of *fig. 13*. In the former, the tracheids, which are fairly uniform in size, are scattered among parenchyma cells that have abundant protoplasm and large nuclei. Before the sporangium is mature, the outer vessels, the protoxylem, begin to collapse. In this type of bundle the phloem is always in a band and shows no tendency to surround the xylem. The amount of phloem is less than in the upper part of the leaf, and by the time the leaf is mature it is almost entirely obliterated by crushing. In following the bundle through the cortex toward the center of the stem the first change seen is a condensation of the bundle by a reduction in the amount of paren-

chyma, although a few parenchyma cells usually remain in the center as long as the leaf trace can be identified (*fig. 15*). For some distance the compact bundle remains distinctly collateral, but the phloem decreases in amount, and near the stele disappears entirely, the leaf trace consisting of a strand of xylem with a few parenchyma cells in the center and a parenchyma sheath. The xylem cells become shorter, and it is no longer possible to distinguish between protoxylem and metaxylem. The next stage is the merging of the tracheids and parenchyma of the various leaf traces to form the central axis.

While in general the leaf traces of the other species are similar to those of *I. echinospora* var. *Flettii*, they present certain interesting variations. The leaf of *I. Tuckermani* var. *Harveyi* is also quadrangular, but is shorter and more rigid. The bundle, however, is not so well developed, either in amount or structure. The tissues are not well differentiated; the phloem in particular is much less sharply differentiated than in the other three species. The thickening of the walls is slight and sieve plates are not evident. The amount of xylem is noticeably less, but the phloem, although not abundant, is not so much reduced as the xylem. In the lower part of the leaf the phloem is a narrow band, but in the upper part of the leaf it forms an arc and tends to surround the xylem. The formation of sieve cells begins in the middle of the band, or arc, and extends around three sides of the xylem. The phloem in the center of the arc is small in amount and more rudimentary than that on either side, so that in places there are indications of a tendency to form two lateral groups. The sieve cells in the lateral groups are smaller, as well as more numerous, and they continue to function long after the first-formed cells have become crushed and functionless. In this species the sporangia are comparatively small.

I. melanopoda has very long, moderately stout leaves, with large sporangia. The leaves have a greater diameter than those of *I. Tuckermani* var. *Harveyi*, but they are very much longer and relatively less stout. The amount of xylem is greater, and the bundle is in general stronger than in the two preceding species. The leaf trace in the cortex of the stem contains on an average twice as many tracheids as that of *I. Tuckermani* var. *Harveyi*, while in the leaf trace above the sporangium there may be three to eight tracheids

instead of one to four, as in *I. echinospora* var. *Flettii* or *I. Tuckermani* var. *Harveyi*. As in the other species, the phloem forms an arc in the upper part of the leaf. As the phloem is abundantly developed at the sides of the arc and poorly developed in the middle, there is a tendency for it to separate into two lateral groups.

The leaves of *I. Nuttallii* differ considerably from those of the other species, both in external appearance and structure. They are triangular in outline, long and very slender, indeed almost thread-like. The sporangia are extremely large, while the leaf tissue, in the sporangium region as well as above, is notably small in amount. The bundle, however, is well developed and larger than in any of the preceding species. It differs conspicuously from those of the other species in the large amount of xylem present in the bundle above the sporangium and in the upper part of the leaf. Although, as in the other species, the bundle becomes reduced above the sporangium, there are usually eight or ten tracheids and sometimes fifteen or sixteen present for a considerable distance above the sporangium. In the region above the sporangium, as in the other species, the protoxylem consists of large cells, which are later replaced by canals. The walls lining the canals are heavily lignified. There is no trace of an endodermis, such as SCOTT and HILL find in *I. Hystrix*. The protoxylem in this region is occasionally mesarch, a few tracheids of the metaxylem developing on the side toward the phloem, although the greater amount of metaxylem is always on the adaxial side of the leaf, where it frequently forms a narrow band. In the region of the sporangium the metaxylem is in the form of a crescent, with the heaviest development often at the ends of the horns. In such cases the bundle tends to become mesarch. The phloem also is well developed and abundant, the sieve tubes regularly separating above the ligule into stout strands. A transverse sieve plate is shown in *fig. 11*.

If the four species are arranged in a series according to the size and development of the leaf traces, the series is as follows: *I. Nuttallii*, *I. melanopoda*, *I. echinospora* var. *Flettii*, *I. Tuckermani* var. *Harveyi*. If the species are arranged according to habitat, from terrestrial to aquatic, the order would be the same, with *I. Nuttallii* as the most terrestrial form and *I. Tuckermani* var. *Harveyi* as the most aquatic. A series arranged according to the size of the leaves is as follows: *I.*

melanopoda, *I. Tuckermani* var. *Harveyi*, *I. echinospora* var. *Flettii*, *I. Nuttallii*. A series according to the size of the sporangia is as follows: *I. Nuttallii*, *I. melanopoda*, *I. echinospora* var. *Flettii*, *I. Tuckermani* var. *Harveyi*. It is perhaps not safe to generalize from a comparison of only four species, but it is worthy of note that the size and development of the bundle in these forms is not related to the size of leaf, but follows the other two series, that of habitat and size of sporangium.

HILL (**13**) calls attention to the presence of two canals in the leaves of *I. Hystrix*, which he regards as representing the parichnos of the Lepidodendreae. In none of the four species examined is there any trace of a canal or any indication of a tendency to form canals. In this respect these species agree with *I. lacustris*.

THE STEM

As is well known, the stem of Isoetes is a short tuberous body, whose vascular axis is very small in proportion to the diameter of the stem. The stem grows in length very slowly, and the apical region is left in a deep pit by the overgrowth of the surrounding region. If the term stele may be applied to a region whose connection with a plerome is far from certain, then the vascular axis may be defined as a non-medullated monostele, consisting of xylem and parenchyma forming a loose network. The xylem is made up of short spiral, annular, and netted tracheids, whose long axis is transverse to the stem (*fig. 22*). The parenchyma cells contain abundant protoplasm, and the nuclei appear active. The xylem axis is surrounded by similar parenchyma cells, one to three layers deep, but in neither young nor old plants is there a trace of phloem. A great many young plants of *I. echinospora* and a few of *I. Tuckermani* var. *Harveyi* were examined, and in all cases the xylem is surrounded by undifferentiated parenchyma. In very young plants the vascular axis is exceedingly small, but there is a constant increase both in length and diameter with the increase in the number of leaves.

The differentiation into protoxylem and metaxylem, which is usually well marked in pteridophytes, is lacking in Isoetes. There is neither a difference in the time of development nor in the character of the elements. A difference in character of elements is not likely to

occur in such a slow-growing stem, and a difference in time would be difficult to detect in a stele whose elements run transversely.

SCOTT and HILL have claimed a slight differentiation in time in certain cases, giving as evidence sections which show tracheids at the outside and parenchyma in the center. But since the xylem is made up of leaf traces which curve down from the leaves, as in *fig. 4*, it is evident that it would be possible to obtain a section which shows this condition without being an example of protoxylem differentiation. In young stems it is not uncommon to find that at least one section shows this apparent differentiation into protoxylem and metaxylem. As was mentioned above, an examination of a series of cross-sections of leaf traces as they approach the central axis indicates that there is no differentiation into protoxylem and metaxylem in that part of the leaf trace. Even if it were present in the leaf traces, the transverse arrangement of the tracheids would cause it to appear in tiers rather than in vertical strands, as in other pteridophyte stems.

The cambium, which appears very early (*fig. 3*), begins its activity in the parenchyma which surrounds the central axis, so that all the tissues which are found outside this thin layer of parenchyma are secondary. The secondary tissues of Isoetes have always been described as anomalous, and so have furnished a fertile field for observation and theorization. The cells which the cambium cuts off externally are ordinary thin-walled parenchyma cells, which have always been called cortex. Whether they represent ancestral phloem is, of course, an interesting question, but there is nothing in their structure to suggest an answer. This is the great storage region of the plant, and the amount of this tissue is much greater than that formed internally by the cambium. In the middle and outer regions of the cortex the cells become rounded, often lobed, as in the mesophyll of leaves (*fig. 18*), and always contain large amounts of starch. The cortex increases its thickness from year to year, although there is a continual loss by the sloughing-off of the outer layers. In the outer region there is little or no starch.

The tissue formed internally to the cambium, the so-called "prismatic layer," is that which has aroused the greatest interest. In a freshly cut section this layer is a glistening white and stands out sharply from the surrounding region. In stained sections it is seen

that the "prismatic layer" is composed of several kinds of cells. In the four species studied there is a considerable range both in the types of cells and in their distribution.

In *I. echinospora* var. *Flettii* there is found scattered irregularly a rather large number of active nucleate parenchyma cells, whose walls are slightly thickened. Associated with them are other cells which are almost or entirely empty and whose walls are not uniformly thickened, but have round, oval, or irregular pits. In such cells the thickening is not very heavy. There are usually other cells in which the thickening is more pronounced and is arranged in irregular bands or rings. In some cells there are heavy bands in addition to the irregular pittings.

Of the four species, *I. Tuckermani* var. *Harveyi* most closely resembles the preceding species, but it differs in several points. There is little or no active parenchyma, the entire tissue consisting of cells whose walls are thickened irregularly. These cells are seldom entirely empty, but usually contain a little protoplasm and small, apparently degenerating, nuclei. The cells are for the most part of the type shown in *fig. 23*, in which the pits are small and irregularly distributed, and there are but faint indications of banding. In the older plants, however, it is not uncommon to find the thickening forming more or less definite bands. In the older parts of old plants the pits become smaller and less prominent, tending to disappear entirely. Sometimes the pits can be seen in sections stained in Bismarck brown, when with a less transparent stain, such as Delafield's hematoxylin, the pits cannot be distinguished, and the walls appear to have a uniform and rather heavy thickening. Apparently the thickening of the cell walls goes on through a period of several years, the first thickening being irregularly distributed, leaving irregular pits, while the later deposits include the whole of the wall and tend to obliterate the pits.

In *I. melanopoda* we have all the types of cells which have been described for *I. echinospora* var. *Flettii:* active parenchyma cells, pitted cells, and cells with irregular thickened bands or rings. The pitted and banded cells are as a rule entirely empty. In addition to these types of cells, however, there are other cells with banded thickenings which are slightly lignified, and also tracheids with spiral or annular thickenings, whose lignification is pronounced, although

not as heavy as in the tracheids of the central axis or of the leaf traces (*fig. 21*). The parenchyma cells, however, have thinner walls and are richer in protoplasm than in the two species just described. The parenchyma and the various types of thickened cells are in most cases distributed irregularly, as is shown in *fig. 26*, although occasionally in the older parts of old stems there are indications of zonation.

I. Nuttallii shows the same type of cells as *I. melanopoda*, but there is a difference in arrangement. This species always shows the zonation which has been described by FARMER for *I. lacustris* and by HEGELMAIER for *I. velata* and *I. Duriaei*. The parenchyma cells form layers one or more cells thick, which alternate with layers composed of the various types of thickened cells (*fig. 25*). The zonation is evident in young plants and is very striking in old plants, especially in the older regions of the "prismatic layer." The thickened cells are usually entirely empty. The parenchyma cells of *I. Nuttallii* are larger, contain more protoplasm, and have thinner walls than those of the first two species. The parenchyma is more like that of *I. melanopoda*, although on the whole the cells are richer in protoplasm than those of the latter species. In the older parts of the stem the thickened empty cells are usually collapsed, so that the zones of thick-walled cells, which alternate with the well-developed parenchyma zones, are apparently much narrower.

Almost all the writers on Isoetes have called attention to the presence of the fine-grained starch in the cells of the "prismatic layer." This was first noted by HEGELMAIER in *I. velata* and *I. Duriaei*, in which the starch-containing parenchyma cells form zones alternating with zones of empty cells. FARMER records the presence of starch in the prismatic layer of *I. lacustris*, in which the starch-filled cells are also arranged in zones. The disposition of the starch was found to vary with the species. In *I. echinospora* var. *Flettii* and *I. melanopoda*, it is present abundantly in the cortex but not at all in the "prismatic layer." In *I. Tuckermani* var. *Harveyi*, in addition to the starch in the cortex, there is starch in the parenchyma in the vascular axis, and in the layer of parenchyma surrounding the axis, but there is none in the "prismatic layer." *I. Nuttallii* shows what seems to be the more common arrangement in the forms previously described; that is, there is abundant starch in the "prismatic layer."

It should be noted that the only one of the four species which contains starch in the "prismatic layer" is the only one which shows well-marked zonation, and is also the one in which the parenchyma cells are the largest and contain the most protoplasm.

Discussion of secondary thickening

A study of the structure of the cells composing the "prismatic layer" is of interest only as affording a basis for an interpretation of the nature of the layer. The interpretation which is accepted in the most comprehensive of all recent works on pteridophytes, BOWER'S *Origin of a land flora*, as well as in CAMPBELL'S *Mosses and ferns* and other current texts, is RUSSOW'S theory, which more recently has received the indorsement of SCOTT. As was mentioned above, they look upon the "prismatic layer" as a complex of tissues, consisting of parenchyma, phloem, and xylem. Among recent writers SMITH is the only one who has even suggested that the tissue may be of a less extraordinary nature.

The position of this layer would naturally lead to the conclusion that it is secondary xylem, but for the fact that its composition is not what we have been accustomed to look upon as characteristic of that tissue. The parenchyma is more abundant, while well-defined tracheids are not only few in number in most species but exceedingly rare or entirely absent in others. In addition to the parenchyma and tracheids, there are the pitted cells, which have been regarded as phloem. It may be well at this point to consider the evidence upon which this claim is made. SCOTT and HILL say:

> The phloem elements have an extremely characteristic structure of their cell walls which comes out conspicuously in sections stained in hematoxylin. Their walls are much pitted, the thicker bands of membranes between the pits forming a lattice-like reticulum. The pits are often subdivided by fine bars into smaller areas. Little of the nature of formed contents can usually be detected, but sometimes small, deeply staining globules are found adhering to the walls, and apparently localized at the pits. In the older parts of the stem the phloem is to a great extent obliterated, dense masses of callus-like substances appearing on the cell walls and almost filling the cavity. The masses stain like callus with coralline-soda, but the other callus reactions tried did not give wholly satisfactory results. We have not investigated the more minute histology of the phloem and thus have not demonstrated the perforations of the thin-walled areas. That may be left to other investigators, but in the meantime, we can scarcely doubt that these enucleate

elements, with the characteristic areolations of their walls, and their agreement in various reactions with the sieve tubes of the leaf, with which we shall see they are continuous, are best to be regarded as themselves representing the sieve tubes of the stem.

If no other explanation of these structures were possible, the reasons given above might be accepted as sufficient proof of the phloem nature of the pitted cells, although the fact of a cambium cutting off both phloem and xylem from the same face is so extraordinary that one does not expect the advocates of such a theory to content themselves with leaving the burden of proof to other investigators. The only analogy is in the case of Dracaena and its allies, whose anomalous secondary thickening has been frequently referred to in the literature on Isoetes. Before RUSSOW'S theory made its appearance, the tissue on the inside of the cambium had been regarded as secondary xylem. This was the very natural interpretation given by HOFMEISTER in his *Higher Cryptogamia* and was accepted, apparently without question, until RUSSOW'S more critical work appeared. If one is not willing to accept the RUSSOW theory, the natural alternative is to regard the "prismatic layer" as secondary xylem. This, of course, requires an explanation of its unusual structure. The presence of a large amount of parenchyma in the secondary wood is unusual but not without parallel, as this is the case in certain Lepidodendreae, e. g., *Lepidophloios fuliginosus*. The presence of unlignified pitted cells, of course, is the situation which has led to controversy, and is the chief point to be explained. However, the presence of pitted cells of a phloem-like aspect does not necessitate the assumption that the cells are phloem, since that structure is found in cells of other tissues, for example, the cortical parenchyma of *Helminthostachys zeylanica*. FARMER and FREEMAN (**10**) in their description of the pits in the cells of the cortical parenchyma say:

> The pits are remarkable, forming, as they do, not merely simple depressions in the walls, but rather being massed together in areas like the pores of a sieve plate. Indeed they may fairly be termed pitted areolae and they do not differ essentially from the actual sieve tubes themselves in the plant.

The presence of cells of this type in tissues which do not even belong to part of the bundle indicates that pitted walls are not necessarily to be taken as an indication of phloem. The usual phloem

tests applied to the "prismatic layer" do not give any positive results. In the case of the cells in question it can be shown that not only are they not phloem but that they are xylem.

A careful examination of the "prismatic layer" of such forms as *I. Nuttallii* and *I. melanopoda* will reveal the fact that, while the secondary tracheids are far removed in appearance and staining reactions from the pitted cells, an almost perfect transition series exists between the two types. Several stages are shown in *fig. 21*. It is possible to trace a series from the tracheids with lignified spiral or annular thickenings, through those with less regular thickenings and with a smaller amount of lignin, to those in which the thickening is very irregular and which have no trace of lignin. A combination of safranin and anilin blue was found to be particularly valuable in revealing slight amounts of lignin. With this variation in wall thickening and lignification, there is correlated a variation in the amount of cell contents. The existence of the transitional stages leads almost inevitably to the conclusion that the various types of cells of the "prismatic layer" differ essentially only in their stage of development, and that the layer accordingly consists of mature tracheids, immature tracheids, and parenchyma. While the series in *I. echinospora* var. *Flettii* is less perfect, it is very suggestive, but that of *I. Tuckermani* var. *Harveyi* is usually too limited to afford much of an indication of the nature of the pitted cells.

The recognized steps in tracheid development are as follows: the more or less regular thickening of the wall; the loss of cell contents; and the lignification of the wall. It should not be assumed, because a parenchyma cell undergoes the first steps of the changes which would lead to the formation of a tracheid, that there is any inherent necessity for their continuance. It is perfectly possible that the course of development might be arrested at any point, and that any or all of these changes might be incomplete, according to the usual standards of completeness. Unfortunately, the cases of secondary growth in modern pteridophytes are so few in number and so limited in extent that there are very few opportunities for comparison; but this very thing—the incomplete development of the tracheids—has been described as characteristic of the secondary xylem of other pteridophytes, and indeed is almost made the test of secondary xylem.

BOODLE (1), in his account of the secondary thickening in the roots of *Ophioglossum vulgatum*, figures both a cross and a longitudinal section of secondary tracheids, which he describes respectively as a "developing tracheid with its protoplasmic contents" and as a "longitudinal section showing part of the xylem with one developing tracheid containing protoplasm and a nucleus." In both these cases the tracheid character of the cell is too pronounced to be questioned. In the case of *Angiopteris evecta*, HILL (14) says with reference to the secondary growth: "Semi-lignified elements with protoplasmic contents are found on the inside of the meristem."

If seems strange indeed, that while, in the case of other pteridophytes, it is taken as a matter of course that tracheids may retain part of their protoplasmic contents and appear in various stages of development, in Isoetes the same condition has been looked upon as an insuperable objection to the tracheid character of the cells in question. It is obviously much more natural to interpret this tissue as a case of arrested development, than to regard it as anything so extraordinary as a combination of xylem and phloem. The fact that we find cases of immature and imperfectly developed secondary xylem in other pteridophytes is more enlightening as a basis of interpretation than is the presence of anomalous secondary thickening in the far-removed Dracaena.

The irregular disposition of the thin areas in the pitted tracheids, while not usual in the pteridophytes, is probably more common than has been supposed. GWYNNE-VAUGHAN (11), in his recent work on the tracheae of ferns, calls attention to the irregularities in the Osmundaceae, Botryopteris, and others, illustrating cases of distinctly pitted walls. FARMER and FREEMAN (10) describe a range of structure in the xylem of *Helminthostachys zeylanica* from tracheids "with characteristic bordered pits of an oval or even circular form" to those "in which the pits assimilate to the more scalariform type met with in the majority of ferns." In Lycopodium in the primary xylem the thin areas are mostly long and narrow, of the scalariform type, but in the slender tracheids they may be round or oval, giving the tracheid a mottled or pitted appearance. A study of the apices of stems of Lycopodium affords an opportunity for a comparison of phloem and young tracheids, a comparison which is of interest as throwing light on

the nature of the pitted cells of Isoetes. In the apices of Lycopodium, where the xylem is not yet mature, it is not difficult to find tracheids that have round or oval pits, and which before they are lignified present a similar appearance to that of the pitted cells of Isoetes. In fact, in *L. pithyoides*, the fully developed sieve cells and the pitted tracheids in which lignification has not yet taken place differ only in the greater regularity of the pitting of the tracheids. If the development of the more slender tracheids of Lycopodium were arrested before lignification had begun, it would be difficult to distinguish sieve cells from tracheids except by position, since both have so nearly the same general appearance and the same reactions to stains. As the disposition of the thickening of the primary tracheids of Isoetes is much less regular than in other pteridophytes, it might reasonably be expected that the secondary xylem would also show irregularities.

One of the reasons given by RUSSOW and subsequent observers for regarding the "prismatic layer" as part phloem, is that it is in direct continuity with the phloem of the leaf traces. I am not disposed to question the nature of the phloem either in the leaves or roots. There is nothing in its position and structure to cause any hesitation about accepting it as phloem. The sieve tubes possess well-defined sieve plates, and the tissue as a whole is so definitely marked off, both in position and development, from the xylem and all adjacent tissues, that there is no apparent reason for questioning its identity as phloem.

There can be no question of the continuity of the old leaf traces and the "prismatic layer" in such cases as are shown in *figs. 19, 20*, but in the case of young leaf traces the point is not so certain. The indications are that the continuity is a result of the overgrowth of the leaf traces by the secondary tissues. *Fig. 17* is a diagram which illustrates a thing that occurs in some if not in all cases where such a continuity exists. In any old stem there are present a very large number of leaf traces, of which only a comparatively few at the top are alive and active. The upper part of the stem is a meristematic region, composed of the meristematic leaf traces and the zone whose lower projection is the cambium. This region is indicated in the diagram by fine dots. The xylem strands of the various leaf traces of that level move in together, forming a more compact region, the vascular axis. The phloem ends in the parenchyma, three or four

cells from the vascular axis, in the region in which the cambium has not yet become defined. As the meristematic region becomes localized, forming the cambium, the parenchyma with which the leaf trace phloem is connected is pushed out farther and farther from the vascular axis by the secondary tissues. The phloem can retain its continuity with this region in three ways: the xylem at the base of the leaf may elongate sufficiently to compensate for the secondary growth in that region; there may be a splitting-apart of the tissues of the bundle, permitting the phloem to slide along the xylem; or the phloem of the leaf trace will be torn apart, leaving one end connected with the "prismatic layer" while the other is carried out into the cortex. Undoubtedly, while the leaf trace is young, there is an adjustment by the first method. It should be noted, however, that the leaf traces which are connected with living leaves are comparatively few in number and are found in that part of the stem in which secondary growth is scarcely observable. At some time in the development of each leaf trace there comes a time when it is no longer capable of extension and is unable to keep pace with the development of the stem. At this point the tissues of the leaf trace give way, and the outer part is carried out into the cortex and finally sloughed off, while the base becomes more or less crushed and remains as a dead stump, which in time may be completely buried in the secondary wood.

While the conditions which have led to the imperfect development of the vascular tissues cannot be known with certainty, among them are doubtless the aquatic habit and the reduction or shortening of the stem. The anatomy of Isoetes does not seem to indicate, as SMITH says (p. 324), "that the genus Isoetes represents a more primitive type of sporophyte than any other vascular plant," but it supports the view of SCOTT that "the group has clearly undergone reduction from some more complex type, and probably from some highly organized form of lycopod, as indicated by the secondary growth, the marked heterospory, and the somewhat complex organization of the leaves and the root-bearing portion of the axis." As a consequence of a shortening or any reduction in stem development, there would naturally be a reduction in the xylem. This might be either in the amount of the xylem, even to the extent of the entire disappearance of the secondary wood, or there might be a reduction in the development

of the xylem. In the other modern pteridophytes it is apparently the former which has taken place, secondary xylem appearing rarely and in small amounts; and, as HILL (**15**) infers from a comparison of the examples of pteridophytes showing the phenomenon, it is more probably an example of reduction than a new development. In Isoetes, however, the reduction in the bundle has not been limited to the xylem portion, but has extended to the whole of the phloem, both primary and secondary.

The position of Isoetes

The phylogenetic connections of Isoetes have been discussed in all recent papers, with the great weight of evidence in favor of a lycopod ancestry. The evidence as to its relationship afforded by its anatomy has been taken up recently by BOWER (**2**), on the basis of the interpretation given by SCOTT and HILL, with the conclusion that Isoetes is in its anatomy a lycopod, with a stem structure which can be explained by regarding it as a stunted lycopod. In his eagerness to show a unity of structure in the Lycopodiales, BOWER makes the following statement (p. 339): "Throughout the Lycopodiales the foliar traces are inserted peripherally, and with only a slight local disturbance upon the periphery of the cauline xylem core." In view of the questionable existence of a cauline portion in the xylem core, there seems to be little justification for so sweeping a statement. It is in this very thing that Isoetes differs markedly from other adult lycopods, although the difference is not of such a character as to make the relationship doubtful. The difference is correlated with the stunted habit, and such differences of body habit have never been admitted to have great weight in determining the larger groupings. The stunted habit of stem is not limited in Lycopodiales to Isoetes, but it occurs also, though of very different type, in Phylloglossum.

Even among those who recognize the strong lycopod affinities of Isoetes, it is suggested occasionally that it might be advisable to separate Isoetes from the lycopods and establish a new order, Isoetales. The present tendency seems to be toward a multiplication of orders, so that it may be well to consider the desirability of it in this case.

The closest connection of Isoetes is, as has been frequently pointed out, with the Lepidodendreae, although it has many points in com-

mon with modern lycopods. The spore-producing members, in structure and development, are unquestionably of the lycopod type, and as such present no obstacle to the retention of the group in the Lycopodiales. With reference to the anatomy my work would seem to strengthen the position of Isoetes in the Lycopodiales. The irregularities of its structure are not of such a nature as to isolate the group. Aside from the possible lack of a cauline portion in the stele, the irregularities of its anatomy are limited to the absence of primary phloem in the stem; the absence of secondary phloem; the lack of differentiation into protoxylem and metaxylem in the stem; the large amount of parenchyma in the secondary wood; and the imperfect development of the wood.

The absence of primary phloem seems to be characteristic of Isoetes. There are no indications of it in the four species described in this paper, and SCOTT and HILL say of *I. Hystrix* "that it is not possible to identify primary phloem with certainty." Although the absence of primary phloem is recorded for juvenile pteridophytes (e.g. *Matonia pectinata*) by TANSLEY and LULHAM, (**23,** p. 482), so far as is known it is present in the stem of all other adult pteridophytes. In this point, then, Isoetes stands alone. The presence of phloem in the leaf traces and roots, and the collateral arrangement of the bundle in the lower part of the leaf trace indicates a descent from a line in which the phloem is present in the stem as a layer around the xylem. It is difficult to tell what importance to attach to the tendency of the leaf trace to become concentric in the middle and upper part; and to the occasional occurrence of mesarch xylem in the leaf trace.

In regard to the next point, the absence of secondary phloem in a stem with a cambium, the isolation of Isoetes is less certain. SCOTT (**20,** p. 167) in discussing the secondary growth of the Lepidodendreae says: "Although the presence of primary phloem can be recognized with certainty, some doubts have been expressed as to the production of secondary phloem by the cambium." It may be well to remember, too, that there are cases among the modern pteridophytes in which secondary xylem is produced, but no secondary phloem has been observed. This suggests that when reduction occurs in a form with secondary thickening, the disappearance of the phloem precedes that of the xylem.

The next peculiarity of the stem anatomy, the absence of differentiation into protoxylem and metaxylem in the vascular axis, is so obviously related to the stunted habit of the stem that it contributes nothing to a discussion of the position of Isoetes.

In the peculiarities of the structure of its secondary wood, Isoetes finds its nearest prototype in certain Lepidodendreae, as has been pointed out by previous writers. The forms which present the greatest similarity of structure are *Lepidophloios fuliginosus* and *Lepidodendron obovatum*. According to SCOTT (**21**) the cambium in *Lepidodendron obovatum* produces parenchyma only and no tracheids; but the cambium in *Lepidophloios fuliginosus* produces either secondary parenchyma only, or secondary parenchyma in which are imbedded groups of tracheids. Certain species of Isoetes present a close approximation to both conditions. In some species the secondary xylem is almost wholly parenchymatous, with no well-formed tracheids and only a few immature tracheids. In other cases there are groups of tracheids associated with the parenchyma, and in addition a certain amount of immature tracheid tissue. Isoetes accordingly differs from these two members of the Lepidodendreae only in the presence of immature tracheids in the secondary xylem. It is not improbable that future work in the Lepidodendreae may bring to light a similar situation in that group.

In point of anatomy, then, there seems to be no adequate ground for the separation of Isoetes from the Lycopodiales.

The strongest argument for the establishment of a separate order has been drawn from the gametophyte generation, in the presence of a multiciliate sperm. While this is a character of great importance, we should consider the extent of our evidence before attaching too much weight to it. It must not be forgotten, moreover, that lycopod sperms occasionally depart from the biciliate type. BRUCHMANN (**4**, p. 32) speaks of the occasional occurrence of sperms with three cilia in *Lycopodium clavatum*. If we reflect that our knowledge of the sperms of the modern genus Lycopodium is limited to those of a few species, and that we have no knowledge at all of the sperms of the more closely related Lepidodendreae, we may be less inclined to regard the character of the sperms as preponderant in determining the position of Isoetes.

Summary

1. The vascular axis is a non-medullated monostele, composed of tracheids and parenchyma. There is no differentiation into protoxylem and metaxylem.

2. There is no primary phloem in the stem. It is found in the leaf traces and root bundles only.

3. The cambium gives rise to cortex on the outside and secondary xylem on the inside. The so-called "prismatic layer" is secondary xylem. The cambium does not form phloem.

4. The secondary xylem consists of various combinations of the following types of cells: (*a*) Spiral and annular tracheids. (*b*) Immature tracheids, slightly lignified, with irregular rings or spiral thickenings. (*c*) Immature tracheids, unlignified, nucleate or enucleate, with irregular rings or spiral thickenings. (*d*) Immature tracheids, nucleate or enucleate, with slightly thickened, pitted walls. (*e*) Parenchyma cells, which may have little protoplasm and small nuclei, or abundant protoplasm and large nuclei.

5. The secondary xylem of *I. Nuttallii* shows zonation. *I. echinospora* var. *Flettii* and *I. Tuckermani* var. *Harveyi* do not. *I. melanopoda* shows it occasionally in old stems. Starch does not occur in the secondary xylem except in the parenchyma zones of *I. Nuttallii*.

6. The root bundles are collateral and monarch. The protoxylem is found on the side away from the phloem and toward the center of the stem, i. e., it is endarch.

7. The leaf traces are collateral, but tend to become concentric in the middle and upper part of the leaf. Thy xylem portion undergoes great reduction above the sporangium, but the phloem is not reduced correspondingly. The sieve plates are transverse.

8. Near the vascular axis the leaf trace does not show differentiation into protoxylem and metaxylem. In the outer part of the cortex and in the region of the sporangium it is usually exarch. In *I. Nuttallii* it is occasionally mesarch above the sporangium and in the region of the sporangium.

This investigation was conducted at the University of Chicago under the direction of Professor JOHN M. COULTER and Dr. W. J.

G. LAND, of whose advice and encouragement I wish to express my keen appreciation.

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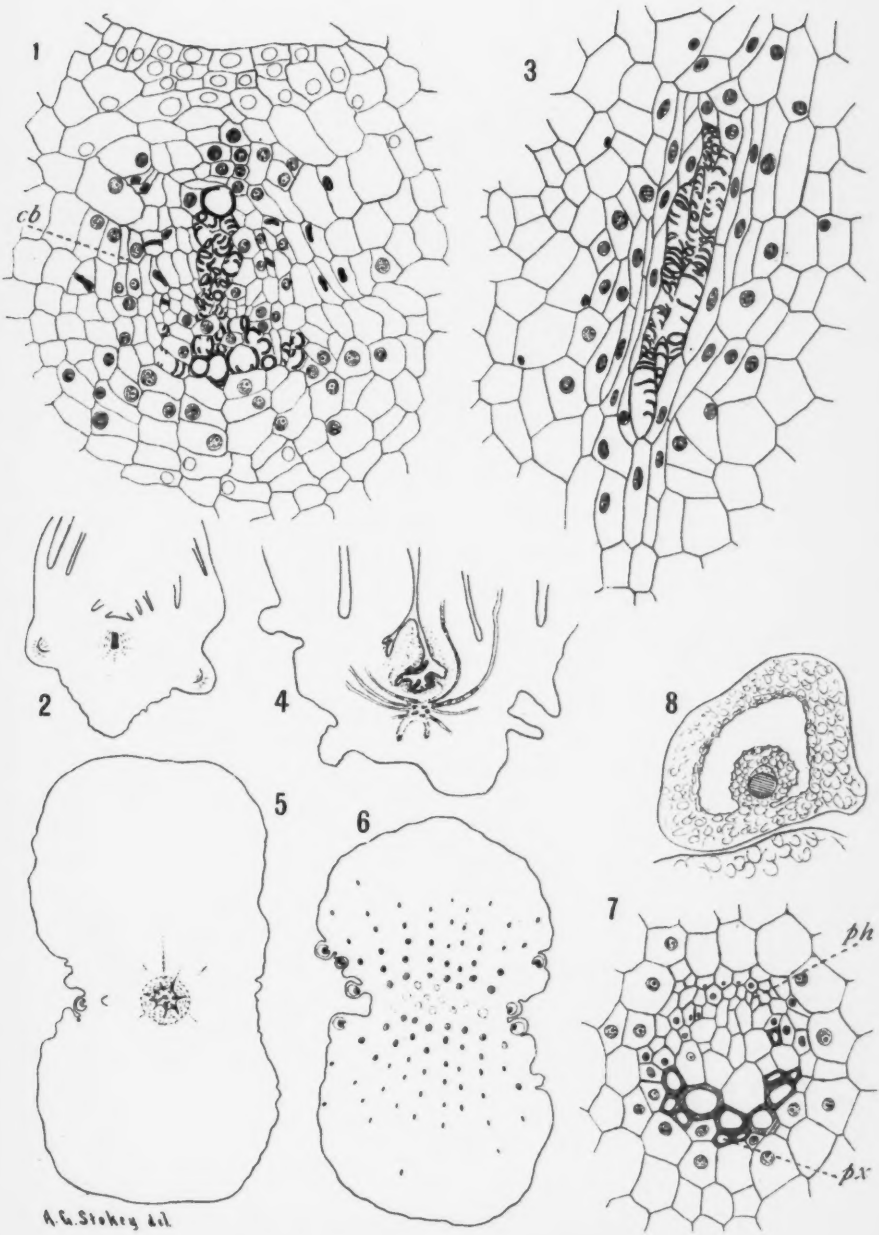
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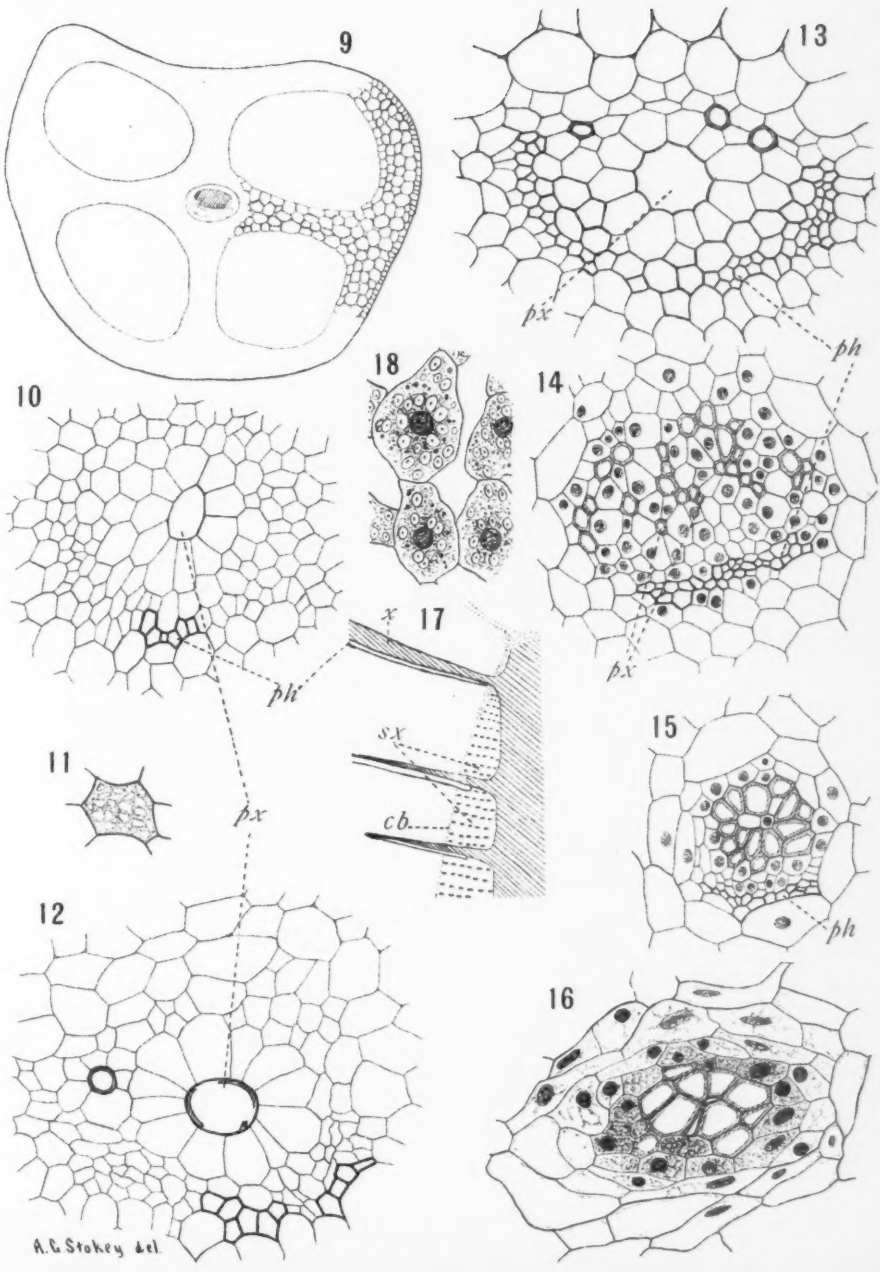
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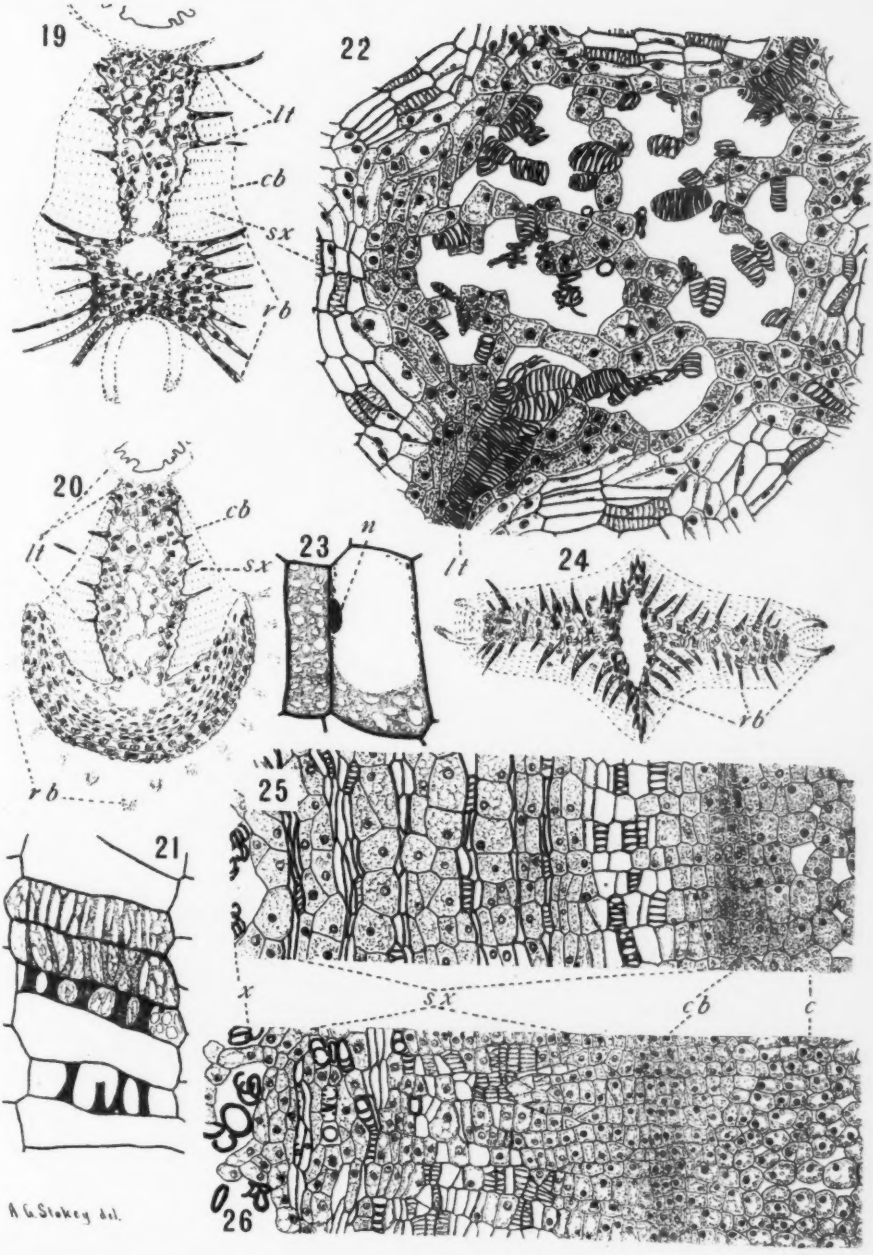

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EXPLANATION OF PLATES XIX–XXI

PLATE XIX

Figs. 1–4.—I. echinospora var. *Flettii. Figs. 5–8.—I. melanopoda*

Fig. 1.—Longitudinal section of the stele of young plant cut in the plane of the furrow. ×380.

Fig. 2.—Longitudinal section of the stem of young plant cut in the plane of the furrow. ×37.

Fig. 3.—Cross-section of the stele of a young plant. ×380.

Fig. 4.—Longitudinal section of a young plant cut across the furrow. ×22.

Fig. 5.—Cross-section of the stem of old plant in the leaf-trace region. ×6.

Fig. 6.—Cross-section of stem below the stele showing root bundles in the cortex. ×6.

Fig. 7.—Cross-section of root bundle before it has left the stem. ×380.

Fig. 8.—Cross-section of mature root. ×48.

PLATE XX

Figs. 9, 10, 12–16.—I. echinospora var. *Flettii. Fig. 11.—I. Nuttallii*

Fig. 9.—Cross-section of mature leaf near the middle. ×37.

Fig. 10.—Cross-section of bundle of young leaf near the tip. ×380.

Fig. 11.—Sieve plate from sieve tube. ×810.

Fig. 12.—Cross-section of bundle of a young leaf near the middle. ×380.

Fig. 13.—Cross-section of bundle of mature leaf cut just above ligule. ×380.

Fig. 14.—Cross-section of leaf trace in cortex just below base of leaf. ×260.

Fig. 15.—Cross-section of leaf trace in cortex half-way between leaf and vascular axis. ×380.

Fig. 16.—Cross-section of leaf trace near the vascular axis. ×380.

Fig. 17.—Diagram to illustrate the relation of leaf traces to secondary wood.

Fig. 18.—Cells of cortex with starch grains. ×380.

PLATE XXI

Figs. 19, 20, 22.—I. echinospora var. *Flettii. Figs. 21, 24, 26.—I. melanopoda*
Fig. 25.—I. Nuttallii. Fig. 23.—I. Tuckermani var. *Harveyi*

Fig. 19.—Longitudinal section of vascular bundle of old plant cut across the furrow. ×22.

Fig. 20.—Longitudinal section of vascular bundle of old plant cut in the plane of the furrow. ×22.

Fig. 21.—Tracheids from secondary xylem at different stages of development. ×810.

Fig. 22.—Cross-section of vascular axis of old plant. ×175.

Fig. 23.—Tracheids from secondary xylem; the cell on the right is sectioned obliquely. ×810.

Fig. 24.—Cross-section of vascular axis through the root region; the long axis is in the plane of the furrow. ×22.

Fig. 25.—Cross-section of stem from the edge of the primary xylem to the cortex, showing zonation in secondary xylem. ×450.

Fig. 26.—Cross-section of the stem from the edge of the primary xylem to the cortex. ×350.

CURRENT LITERATURE

BOOK REVIEWS

Evolution of the filicinean vascular system

Professor Tansley[1] has done well to gather under one cover his lectures on the vascular system of ferns, previously published in the *New Phytologist*. The attempt is made "to gather together the results that have accrued from the researches on the morphology of the vascular system of ferns which have been undertaken during the last few years, and to present these results from an evolutionary standpoint." The first lecture discusses various theories which have been advanced to account for the origin of the main phyla of Pteridophyta. The author favors the view of a direct derivation from Algae in which an alternation of generations had already been established. Accordingly, the sporophyte of pteridophytes would not correspond to that of bryophytes, in which an antithetic alternation of generations seems to have been worked out. The author admits that the presence of an archegonium in both mosses and ferns is an obstacle to this view. Assuming a monophyletic origin for pteridophytes, the view is advanced that the ancestral form was one with a radially organized axis having branches, some of which became specialized as leaves. These leaves were relatively large, and appear to have branched dichotomously; hence the derivation of Filicales from a lycopod form is not credited. It is even suggested that small-leaved forms, such as Lycopodium, may have been derived by reduction from megaphyllous ancestors. The whole scheme of phylogeny proposed is largely speculative, but such attempts will be welcomed by those who find difficulty in accepting BOWER'S well-known hypothesis.

In the second lecture the Botryopterideae are reviewed, and much scattered information on this group is rendered available. Proceeding from the protostelic condition exhibited by Grammatopteris, the complications shown by Zygopteris and other genera are discussed, and the conclusion is reached that this group stands near the ancestors of the different phyla of fern-like plants. Among the Hymenophyllaceae the mode of exit of the leaf-traces lends support to the author's view of the identical nature of leaf strand and stem stele. In discussing this family, as well as the Gleicheniaceae and Schizaeaceae, BOODLE'S work is freely drawn upon and is presented from the evolutionary standpoint. Phylogeny as indicated by the stele is compared with that inferred from the sporangia, and a general correspondence is claimed, though the latter criterion is considered to be the more reliable.

In the sixth lecture the evolution of a protostele into a solenostele (siphonostele) is considered with reference to the examples found in the foregoing families.

[1] TANSLEY, A. G., Lectures on the evolution of the filicinean vascular system. New Phytologist reprint no. 2. Paper. 8vo. pp. 144. Cambridge: The Author. 1908. 3*s*. 6*d*.

Although no explicit statement is made, the reader is apparently left to infer that there are two modes of origin of a hollow stele: (1) one in which the central tracheids are replaced by parenchyma (Schizaea), (2) one in which fundamental tissue passes into "pockets" at the leaf gaps and becomes continuous with the tissue in contiguous pockets (Alsophila). Although the latter view of the origin of "pith" is essentially that of JEFFREY, no mention of the fact is made in the text, but such reference is relegated to the preface, where the author disclaims adherence to this view. The evolution of solenostely into dictyostely, and finally into polycycly is clearly traced, and the complicated condition found in Marattiaceae is adequately illustrated by diagrams from various sources.

Concerning the Osmundaceae, the conclusion is reached that the stele does not represent a reduced type, but shows a gradual progression from the condition seen in Botryopterideae, from which group the Osmundaceae have probably been derived. The recent work of KIDSTON and GWYNNE-VAUGHAN on fossil members of the group is quoted in defense of this position.

In a succeeding lecture the evolution of the leaf-trace is outlined, and it is shown that elaborations of the primitively simple curved trace follow upon increase in the leaf-surface, and in turn bring about increasing complexity in the central cylinder of the stem. According to the author's view "the leaf-trace leads, and the stele follows, in the course of evolution." The ontogeny of the vascular system is next summarized, and a final lecture is devoted to a comparison of the vascular system of various phyla. The criticisms of JEFFREY'S primary groups Lycopsida and Pteropsida have already been dealt with in this journal[2].—M. A. CHRYSLER.

The American Breeders' Asssociation

The fourth annual report of the American Breeders' Association[3] is, in a number of features, a decided improvement over previous volumes. The same high standard of matter is maintained as in previous reports, but there is more of it; it is printed on better paper; and contains numerous fine half-tone engravings. Unlike many publications which are more or less influenced by practical considerations, the articles presented in the reports of the American Breeders' Association appear to suffer no diminution of scientific value because of the large contingent of practical breeders among its membership and on its programs. Almost every phase of practical and theoretical breeding of plants and animals, as well as two interesting reports upon eugenics, the new science of improvement of the human race, are included. Papers of importance from the standpoint of the practical plant-breeder include several upon the production of disease-resistance in various plants by W. A. ORTON, P. K. BLINN, and H. L. BOLLEY;

[2] JEFFREY, E. C. Are there foliar gaps in the Lycopsida? BOT. GAZETTE **46**:241–258. *pls. 17, 18.* 1908.

[3] Report of the American Breeders' Association. Vol. IV. pp. 373. *pls. 3, figs. 74.* 1908.

the improvement of apples and other tree and vine fruits, by S. A. BEACH, W. T. MACOUN, and J. A. BURTON; the breeding of cereals by L. S. KLINK and C. E. SAUNDERS; the improvement of hops by selection and breeding by W. W. STOCKBERGER; on cotton-breeding by DAVID COKER, H. J. WEBBER, and D. A. SAUNDERS; the breeding of fiber crops, by J. H. SHEPPARD, L. H. DEWEY, FRITZ KNORR, and H. L. BOLLEY; the breeding of vegetables, by W. W. TRACY; roses by PETER BISSETT, and W. VAN FLEET; tobacco by A. D. SHAMEL, J. B. STEWARD, A. D. SELBY, and W. H. SCHERFFIUS; carnations by C. W. WARD; forage crops by T. F. HUNT and H. S. ALLARD; and forest and nut trees by GIFFORD PINCHOT, W. L. JEPSON, and G. L. CLOTHIER. In all of these articles, as well as in a number dealing with animal breeding, there are many facts recorded which are of more than passing scientific interest. Papers of a more strictly theoretical scientific character are: "Organic correlations," by E. M. EAST, "Some gaps in our knowledge of heredity," by H. J. WEBBER, "The composition of a field of maize," by G. H. SHULL, "Recent advances in the theory of heredity," by C. B. DAVENPORT, "Color factors in mammals," by W. J. SPILLMAN, and "Mendelian phenomena and discontinuous variation," by W. J. SPILLMAN. The wide range of subjects and the almost uniform high excellence of the papers and reports included in this volume show that the American Breeders' Association has a large mission to fill, and that it is filling it creditably. These annual reports are made the treasure-house of all the best things gained in the experience of our foremost practical breeders and students of heredity during the progress of their work. The efforts made by the practical breeders to present their experience in as proper scientific form as possible, and to interpret those experiences in the light of the latest scientific results, and the efforts of the scientific breeders to state their results in as simple, direct, and comprehensible a manner as possible, have a most salutary effect upon all those connected with the American Breeders' Association, and must continue to supply us with the best annual crops of information regarding the factors which enter into the breeder's work, whatever may be his motive in breeding.—GEORGE H. SHULL.

MINOR NOTICES

Sertum Madagascariense.[4]—This paper is based on two collections of plants made in Madagascar, one by JOHN GUILLOT in the district of Vatomandry on the east coast and the other by HENRI RUSILLON on the plateau of Imerina. The first part of the work consists of a brief consideration of the botanical geography; and in the second part the author in collaboration with several prominent European specialists, gives a list of the species. Among the plants recorded 26 species and 4 varieties are described as new to science. The larger and more critical genera are accompanied by analytical keys to the species, and several text-figures have been introduced. A complete index to the vernacular and scientific names is also

[4] HOCHREUTINER, B. P. G., Sertum Madagascariense. Ann. Conserv. et Jard. Bot. Genève 11–12:35–135. *figs.* 23. 1907–1908.

added. The work is a notable contribution to our knowledge of the flora of Madagascar.—J. M. GREENMAN.

North American Flora.[5]—Part 4 of Vol. XXII contains a continuation of Dr. P. A. RYDBERG's elaboration of the Rosaceae. The groups treated are Potentilla and the related genera. In all sixteen genera are here considered, and to these the author refers 277 species, of which 70, approximately one-fourth, are described as new. Potentilla leads with 176 recognized species, 44 being published as new to science. Two new genera (*Zygalchemilla* and *Lachemilla*) are proposed.—J. M. GREENMAN.

NOTES FOR STUDENTS

Longevity of seeds.—In a long paper[6] EWART classifies seeds according to their duration of life under optimal conditions as: microbiotic seeds, with a longevity of less than 3 years; mesobiotic, with a longevity of 3 to 15 years; and macrobiotic, with a longevity of 15 to 100 years. Most of the paper (175 out of 210 pages) is taken up with a table, drawn from the works of various investigators, showing the age, percentage of vitality, etc., of various stored and buried seeds. EWART says: "Longevity depends not on the food materials or seed coats, but upon how long the inert protein molecules, into which the living protoplasm disintegrates when drying, retain the molecular grouping which permits of their recombination to form the active protoplasmic molecule when the seed is moistened and supplied with oxygen." Longevity, however, he holds, is in general found in seeds with seed coats impervious to water, and asserts that this impermeability is due to cuticular structures in almost all cases examined. In *Adansonia digitata*, on the other hand, all layers of the coats are equally resistant to water.

He agrees with CROCKER that seed-coat characters rather than embryo characters account for the greater number of cases of delayed germination, and he makes considerable use of the data of this writer as evidence on this point. He believes that the longevity of seeds in soil is far less than is generally assumed. The maximal duration of the seeds of certain Leguminosae under optimal conditions is stated to be between 150 and 250 years, and of Malvaceae and Nympheaceae between 50 and 150 years. An appendix by Miss JEAN WHITE gives the structure of the coats of various resistant seeds. The body of the work is marred by a number of inexcusable errors in the statement of the results of other investigators. —WM. CROCKER.

Enzymes.—GRÜSS has suggested[7] a method of capillary analysis of enzymes for which he claims considerable value. It consists in pulverizing a portion of the

[5] North American Flora, Vol. XXII, Part 4, pp. 293–388. New York Botanical Garden, 1908.

[6] EWART, ALFRED J., On the longevity of seeds. Proc. Roy. Soc. Victoria. N.S. **21**:1–20. *pls. 1, 2.* 1908.

[7] GRÜSS, J., Kapillaranalyse einiger Enzyme. Ber. Deutsch. Bot. Gesells. **26a**: 620–626. 1908.

tissue containing the enzyme in a small amount of glycerin and placing this on a filter paper. From this mass the water circle spreads and the enzymes can be located at various radial distances from the center. In dealing with oxidases the whole process is performed in an atmosphere of hydrogen. It is not evident that this method is of any great value further than as a mere means of demonstrating the presence of certain enzymes. GRÜSS also claims by it to gain evidence that cytase is not distinct from diastase, and believes he has shown in a number of other cases that a single enzyme performs several catalytic functions. His arguments against the specificity of enzymes are to a degree plausible, but are far from conclusive.

GRÜSS also asserts,[8] on the basis of considerable experimental evidence, that the reducing power of fermenting yeast attributed to the action of reductase can be accounted for by the nascent hydrogen set free by the hydrogenase of the yeast. In the presence of fermenting yeast the reduction of sodium seleniate and sulfur occur as they do when treated with nascent hydrogen. He finds no evidence for postulating reductase in yeast. He believes that the fungi in general possess hydrogenase and not reductase. If this be true the reductions carried on by this group of plants are strikingly similar to the simplest reductions in the chemical laboratory. He agrees that yeast and other fungi show a very slight reducing power not due to hydrogenase, but the substance that produces this slight reduction shows none of the characteristics of an enzyme.—WM. CROCKER.

Germination in Rhinanthaceae.—SPERLICH[9] believes he has demonstrated that the germination of the seeds of the partially parasitic species, *Melampyrum silvaticum*, *M. arvense*, and *Alectorolophus hirsutus*, is greatly hastened by the presence of the host plant. These seeds show a considerable rest period and he concludes that the favorable action of the host is evident only up to the completion of the "after-ripening." A close examination of his data shows that his conclusions do not necessarily follow from them. He always gets a very low percentage of germination and great variations in results from similar cultures. This indicates the presence of some uncontrolled factor. On discussing "after-ripening" he makes no mention of the general connection of delayed and distributed germination with the seed coats, but attributes these phenomena to embryo characters. He apparently has no knowledge of the literature on the subject. One wonders if his results are not merely the measurement of seed-coat effects. He certainly has not demonstrated dormancy in the embryo itself, which is the first step in establishing his main position. The disposition of a number of German investigators to refer the phenomena of "after-ripening" to the mysteries of the protoplasm is to be deplored, especially when a thorough examination of the facts will often furnish a very simple explanation. It must not be forgotten, however,

[8] GRÜSS, J., Hydrogenase oder Reduktase? *Idem:* 627–630. 1908.

[9] SPERLICH, ADOLPH, Ist bei grünen Rhinanthaceen ein von einen pflanzlichen Organismus ausgehender äusserer Keimungsreiz nachweisbar? Ber. Deutsch. Bot. Gesells **26a**:574–587. 1908.

that it has been clearly proved that the fungus of the host is necessary for the normal germination of the seeds of many orchids; but even here our knowledge is of little scientific significance until we know the exact method of the action of the fungus, whether its effect is due to the secretion of certain chemical compounds, which aid in water absorption, or to some other influence.—WM. CROCKER.

Chromogens.—TAMMES[10] reports a new chromogen, dipsacan, which is present in all the genera and species of Dipsaceae examined. Dipsacan has many points of resemblance to isatan and indican, yet it shows points of difference from both these, as well as from the pseudoindicans of the Acanthaceae. At temperatures above 35° C., in the presence of oxygen and water, dipsacan is transformed to a blue pigment, dipsacotin. The optimum temperature for this transformation is 100° C. At high temperatures, or at ordinary temperatures through the action of benzin, phenol, or dipsacase, an enzyme of this family of plants, dipsacan is transformed to a yellow-red pigment in the entire absence of oxygen. Upon admission of oxygen this pigment is transformed to dipsacotin.

PALLADIN[11] has already urged that chromogens are universally present in actively respiring portions of plants and that they are products of respiration. TAMMES's results agree with this conception, for dipsacan is found to be most abundant in the most active portions of the plants and in those plants that are in the best condition for growth; otherwise only traces of dipsacan appear.

TAMMES suggests that dipsacan may be a glucoside, and that the yellow-red pigment, which originates independent of oxygen, is one the products of the hydrolysis; but it is not known that sugar is also a product. The formation of the dipsacotin from the yellow-red pigment is a matter of oxidation, as PALLADIN has shown is the case in the production of the pigments from numerous chromogens he has studied. It strikes one as possible that the formation of the chromatic materials in general requires both hydrolysis and oxidation. This would line up all these chromogens with indican.—WM. CROCKER.

Germination and light.—KINZEL[12] publishes another paper on the effect of light on germination of seeds, confirming the results of former papers and adding a number of species to those favored in germination by light.

In a discussion of "after-ripening" he states that the several years' delay in germination shown by the ripe seeds of *Thlaspi arvense* is due to the character of the embryo and not to the character of the coat, for the coat is very delicate. In an article published in 1906,[13] the reviewer has shown that the very marked delay

[10] TAMMES, TINE, Dipsacan and Dipsacotin, ein neues Chromogen und ein neuer Farbstoff der Dipsaceae. Recueil Trav. Bot. Neerland **5**:—. (pp. 48.) 1908.

[11] PALLADIN, W., Die Verbreitung der Atmungschromogens bei den Pflanzen. Ber. Deutsch. Bot. Gesells. **26a**: 378–389. 1908.

[12] KINZEL, WILHELM, Lichtkeimung. Einige bestätigende und erganzende Bemerkungen zu den vorläufigen Mitteilungen von 1907 und 1908. Ber. Deutsch. Bot. Gesells. **26a**:631–645. 1908.

[13] CROCKER, WM., Rôle of seed coats in delayed germination. BOT. GAZETTE **42**:282. 1906.

in these seeds is entirely due to the coats. The delicacy of the coat is no criterion of its effect, for certainly few seed coats are more delicate than that of the upper seed of the cocklebur, yet it generally secures a delay of a year or more.

It is surprising that experimenters are so slow to see that the proper test for dormancy of an embryo is to free it from incasing membranes with aseptic precautions and then to subject it to germinative conditions. This treatment will probably show the cause of most cases of delay to be in structures surrounding the embryo. If such treatment shows real dormancy of the embryo, as in the radicle of the hawthorn,[14] it is then necessary to find the particular process that is delinquent. This is certainly possible in the light of the great progress that is being made in studying the catalytic nature of protoplasmic activity. When cases of delayed germination are investigated in this way, we may hope for progress. But to assume dormancy is merely marking time and leaves the physiology of delayed germination, as it is now, more than ten years behind other phases of plant physiology.—WM. CROCKER.

Permeability.—RUHLAND[15] holds entirely untenable OVERTON'S theory of the permeability of protoplasm, both in its original form and as modified by NATHANSOHN. In the main RUHLAND offers the same sort of evidence as has ROBERTSON[16] from the animal side. RUHLAND studied the ability of various organic dyes to enter the living cell. Malachite green and thionin, both almost insoluble in lipoids, enter the live cells readily, while rhodamin, highly soluble in lipoids, hardly penetrates them at all. He cites a number of other dye stuffs where just the opposite behavior occurs to that expected by the lipoid theory. Both the acid and basic phthaleins are highly soluble in lipoids. The former penetrate living cells readily while the latter scarcely enter at all. RUHLAND says we have no hint of a reason for this behavior. RUHLAND and ROBERTSON agree that a thin layer of lipoids often exists near the periphery of the protoplasm. They believe, however, that it is not continuous in any case, but only fills interstices of the protein matter. ROBERTSON attributes the permeable character to the nature of the outer, very sparingly soluble, protein layer.—WM. CROCKER.

Reproduction and stimuli.—FREUND[17] has done a rather elaborate piece of work on the effect of external conditions upon the asexual reproduction of Oedogonium and Haematococcus. He finds that previous culture conditions determine very largely the effect of any reagent. Of the several methods he found of producing this response two illustrations will suffice to give an idea of the work. After

[14] CROCKER, WM., Longevity of seeds. BOT. GAZETTE **47**:69–72. 1909.

[15] RUHLAND, W., Beiträge zur Kenntnis der Permeabilität der Plasmahaut. Jahrb. Wiss. Bot. **46**:1–54. 1908.

[16] ROBERTSON, T. B., On the nature of the superficial layer in cells and its relation to their permeability and to the staining of tissues by dyes. Journ. Biol. Chem. **4**: 1–34. 1908.

[17] FREUND, HANS., Neue Versuche über die Wirkung der Aussenwelt auf die ungeschlechtliche Fortpflanzung der Algen. Flora **99**:41–100. 1908.

Oedogonium has grown for a considerable time in distilled water in the light, a transfer to darkness or to a dilute nutrient solution causes a development of zoospores. Resting cells of Haematococcus, kept in darkness for some time, produce swarmspores upon being illuminated or supplied with cane or grape sugar.

FREUND finds the chemical nature of the medium rather than its physical or osmotic character the important consideration in the asexual reproduction. In contrast to this, LIVINGSTON found the osmotic character of the media the main consideration in determing the form of Stigeoclonium.—WM. CROCKER.

Phototropic response.—BLAAUW,[18] working with the seedling of *Avena sativa*, concludes that the intensity of the light, multiplied by the least time of exposure necessary to give a phototropic response, is approximately a constant. The intensities used varied from 0.000439 to 26,520 Hefner candles, and the time of exposure from 13 hr. to 0.001 sec. The product of the exposure in seconds by the intensity in Hefner candles averages about 21 and varies from 16.9 to 26.5. This, of course, hardly looks like a constant; but the variation is attributed to the individual differences of the seedlings. The intensity of the light was measured with a Weber photometer, and the observation of the response was made two hours after the end of the exposure. The author says, "The essential condition for the production of a phototropic curvature is the supply of a definite quantity of radiant energy; whether this quantity be supplied in a very short time or extremely slowly, is a matter of indifference."—WM. CROCKER.

Spraying potatoes.—A recent bulletin[19] summarizes the results of the seventh year's work in the ten-year series of potato-spraying experiments begun in New York in 1902. In the ten-year experiments at Geneva, six sprayings increased the yield 39 bushels per acre and three sprayings increased it 29.5 bushels, although both early and late blight were wholly absent and there were but few flea beetles. In fourteen "farmers' business experiments," including 200 acres, the average gain due to spraying was 18.5 bushels per acre; the average total expense of spraying, $4.30 per acre; and the average net profit, $8.53 per acre. In five of the experiments spraying was unprofitable. Eleven "volunteer experimenters" reported gains averaging 66.3 bushels per acre.—F. L. STEVENS.

Alfalfa.—An exceedingly interesting and comprehensive bulletin concerning alfalfa[20] has just appeared from the New York Experiment Station. Among the subjects treated are the following: Varieties grown, uncongenial soil conditions,

[18] WENT, F. A. F. C., On the investigations of Mr. A. H. BLAAUW on the relation between intensity of light and the length of illumination in the phototropic curvatures in seedlings of *Avena sativa*. Reprint from Proc. Kon. Akad. Wetens. Amsterdam, Sept. 26, 1908. pp. 5.

[19] STEWART, F. C., FRENCH, G. T., and SIRRINE, F. A., N. Y. Agric. Exp. Sta. Bull. 311. January, 1909.

[20] STEWART, F. C., FRENCH, G. T., AND WILSON, J. K., Troubles of alfalfa in New York. N. Y. Agric. Exp. Sta. Bull. 305. November, 1908.

winter injury, failure of the seed crop, viability of the seed, impure and adulterated seed, fodder, yellow trefoil, weeds. Among the fungous diseases discussed are: Leaf spot, wilt, anthracnose, root-rot and damping off, downy mildew, Ascochyta leaf-spot, Stagnospora leaf-spot, Cercospora leaf-spot, Alternaria disease (?) of seed, frost blisters on leaves, insect enemies, and root-knot; also, as diseases of unknown cause, white spot, yellow top, pitting of the tap-root, and bundle blackening in the tap-root.—F. L. STEVENS.

Barium and loco.—In a bulletin on loco weeds[21] CRAWFORD says: "The inorganic constituents, especially barium, are responsible for this action, at least in plants collected at Hugo, Colo. Perhaps in other portions of the country other poisonous principles may be found." *Astragalus mollissimus* and *Aragallus Lamberti* were most fully studied, but other species of these genera, as well as various other genera, have been reported as producing loco.—WM. CROCKER.

Protection against heating.—WIESNER holds that the distribution of green tissues into small leaves or finely divided leaves is a mode of protection against overheating by the sun, and adduces observations and experiments in support therefor.[22] This protection is secured by the small size of the parts which expose a relatively large surface for radiation and at the same time permit many light rays to pass them by.—C. R. B.

Balanced solutions.—OSTERHOUT continues his studies upon balanced solutions with plants,[23] reporting that Na ions, by reducing the toxicity of K, NH_4, Mg, and Ca ions, are an important, and in some marine algae an indispensable, protection. He finds that there is no essential difference between plants and animals in this respect.—WM. CROCKER.

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[21] CRAWFORD, A. C., Barium, a cause of the loco-weed disease. Bur. Plant Ind., U. S. Dept. Agric. Bull. 129. pp. 87. 1908.

[22] WIESNER, J., Versuche über die Wärmeverhältnisse kleiner, insbesondere linear geformter, von der Sonne bestrahlter Pflanzenorgane. Ber. Deutsch. Bot. Gesells. **26a**:702–711. 1908.

[23] OSTERHOUT, W. J. V., Die Schutzwirkung des Natriums für Pflanzen. Jahrb. Bot. **46**:121–136. 1908.